BELLCOMM, INC.

SUBJECT: Description of S-II Stage Systems - Case 320

DATE: April 21, 1967

FROM: T. H. Crowe

ABSTRACT

This memorandum provides a description of S-II stage systems in sufficient detail to enable the reader to assess the impact of major problems or changes to the systems.

(NASA-CR-154895) DESCRIPTION OF S-2 STAGE SYSTEMS (Bellcomm, Inc.) 41 p

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MEMORANDUM FOR FILE

Introduction

The purpose of this memorandum is to provide a description of the S-II stage systems in sufficient detail to enable the reader to assess the impact of major changes to the systems. The author has attempted to provide material which reflects the configuration of the early S-II stages.

The systems discussed in the memo are:

Engine Chilldown System
Propellant Feed System
Propellant Management System
Stage Separation System
Propellant Dispersion System
Flight Control System
Electrical Power System
Electrical Control System
Instrumentation System
Radio Frequency System
Conditioning and Thermal Control System
Leak Detection and Purge System

A description of the structure is contained in the author's memorandum, "Description of S-II Stage Structures" dated April 20, 1967. The J-2 engines are not discussed as a system nor is the Emergency Detection System.

Figure 1 is a line drawing of the stage showing the location of some of the major components of the systems.

Engine Chilldown System

The engine thrust chamber jacket is chilled to -200° F ± 50° prior to launch by circulating cold helium through the jacket from ground support equipment. The jacket is further chilled down just prior to engine ignition by bleeding LH_2 from the fuel tank through the jacket overboard through the thrust chamber.

[redacted]

Chilldown of LH_2 and LOX engine feed lines, pumps and gas generators is commenced prior to launch and continues until just before S-II ignition.

Chilldown of the LH_2 systems is accomplished by pumping LH_2 from the LH_2 tank by a submerged pump through the main fuel lines, engine fuel pumps, gas generator bleed valves and then back to the tank. Figure 2 is a sketch of the LH_2 recirculation system.

Chilldown of the LOX systems is accomplished by circulating LOX from the LOX tank through the prevalves, main LOX lines, engine LOX pump, gas generator bleed valves and then back to the tank. Circulation is by helium injection from GSE prior to launch and from an on-board tank after launch. Figure 3 is a sketch of the LOX recirculation system.

<u>Propellant Feed System</u>

The propellant feed system consists of the propellant tanks, pressurization systems and the engine feed systems. Figure 4 is a sketch of the propellant feed system.

The LOX tank has a capacity of 81,500 gallons. It is filled and drained through a single line which attaches to the tank at the sump located at the bottom of the tank. Maximum fill rate is 4850-5150 gallons per minute. Maximum drain rate is 3300-3360 gallons per minute.

The LH_2 tank has a capacity of 266,000 gallons. It is filled and drained through a single line located in the lower cylindrical section of the tank. Maximum fill rate is 9700-10,300 gallons per minute. Maximum drain rate is 6600-6740 gallons per minute.

The LOX tank is pressurized prior to launch with helium supplied by GSE and during S-IC boost and engine start with helium from a 1.5 cubic foot sphere mounted on the thrust structure. During the S-II boost phase, the LOX tank is pressurized with GOX obtained by passing LOX through a heat exchanger located in the LOX turbine exhaust line of each engine. Tank vent valves are provided to control maximum pressures and to permit venting during LOX loading. Figure 5 is a sketch of the LOX pressurization system.

The LH_2 tank is pressurized prior to launch with helium supplied by GSE and during S-IC boost and engine start with helium from two 6 cubic foot spheres located on the forward skirt. During S-II boost, the LH_2 tank is pressurized with gaseous H_2 bled off from each engine at a point between the thrust chamber cooling system and the injector. Tank vent valves are provided to control maximum pressure and to permit venting during LH_2 loading. Figure 6 is a sketch of the LH_2 pressurization system.

The principal components of the engine feed system are the following for each engine: LH_2 feed line, LH_2 prevalve, LOX feed line, LOX prevalve, fuel turbo-pump,oxidizer turbo-pump, propellant utilization valve, main fuel valve, main oxygen valve, GH_2 start tank, gas generator, boot strap valves and piping for LH_2 and LOX, gas generator exhaust piping and valves.

LH_2 feed lines are routed from the bottom of the LH_2 tank to the fuel turbo-pump inlet. The prevalves, normally open emergency shut-off valves, are located between the tank and the pump. From the pump the LH_2 flows to the main fuel valve and from there to a fuel manifold. From the manifold it passes through axial tubes which make up the thrust chamber and nozzle wall. The LH_2 cools the chamber and after it passes through the tubes is GH_2. The GH_2 is then manifolded to the injectors.

The LOX feed lines are routed from the LOX tank sump to the inlet of the oxidizer turbo-pump. The prevalves, normally open emergency shut-off valves, are located between the tank and the pump. The propellant utilization valve is mounted on the outlet of the pump. It is a motor driven valve controlled by the propellant utilization system. Its purpose is to control the mixture ratio by bypassing LOX from the pump outlet to the pump inlet. From the pump the LOX flows to the main oxygen valve. From the main oxygen valve the LOX flows to the engine injector manifold.

At the beginning of the start sequence the fuel turbo-pump is rotated by bleeding GH_2 from the precharged start tank. The exhaust from the fuel turbo-pump is used to drive the oxidizer pump. A bypass valve between the oxidizer pump and the fuel pump controls the ratio of rpm between the pumps. As the pumps build up speed the outlet pressure increases, and LOX and LH_2 are bled off the outlet side of the pump to the gas generator. The gas generator is ignited and the start tank is shut off. The pumps are then driven by the products of combustion of the gas generator. The exhaust of the oxidizer pump passes through a heat exchanger which converts LOX to GOX for LOX tank pressurization. The exhaust gases then go to the exhaust manifold and from there overboard through the engine thrust chamber. Figure 7 is a diagram of the engine feed system.

Propellant Management System

The propellant management system provides outputs for control of propellant loading, monitoring of propellant quantities, maintenance of proper mass ratio during S-II boost, and propellant depletion cutoff signal. Both continuous level and point level sensors are utilized in the system.

Figure 8 is a sketch of the installation of the continuous level sensor in the LH_2 tank and Figure 9 is a sketch of the sensor itself. Installation of the continuous level sensor in the LOX tank is vertical near the centerline of the tank. Figure 10 is a sketch of the point sensor installation in the stage. These sensors are installed on a mast parallel to the continuous sensors, near each LH_2 feed line outlet, and near each LOX feed line outlet.

The continuous level systems are used to control propellant loading, to provide inputs to the propellant utilization computer and to monitor propellant mass.

The point sensors are used to provide a discrete overfill signal, to provide engine cutoff signal, (two out of five voting logic from either tank triggers the signal) and for propellant level monitoring. Figure 11 is a block diagram of the propellant utilization, loading and mass indication system.

Stage Separation System

The S-II stage separation is a dual plane separation. The first separation plane is 23 inches forward of the field splice between the S-IC stage and the S-II stage.

The second plane is at the interface between the aft interstage and the aft skirt. Mounted on the aft interstage, forward of the first separation plane,are eight ullage rockets which in combination with the S-IC retrorockets provide the acceleration necessary for first plane separation.

The structural joints at the separation planes are formed by tension tie straps. Mounted over these straps is a linear shaped charge (LSC) which is fired by an exploding bridge wire (EBW) detonator. Figure 12 shows the separation plane construction. The ullage motor ignition charge is distributed to pyrogen initiators in each motor by a confined detonating fuse (CDF) train which is initiated by an EBW detonator. The firing circuits for the LSC and the ullage motors are redundant. Figure 13 depicts these circuits.

Each ullage motor produces a thrust of approximately 22,800 pounds for four seconds. The motor nozzles are canted 10° from the stage center line.

The separation sequence commences with shutdown of the S-IC engines. Following this, an accelerometer actuated switch fires the ullage motors when acceleration had decreased to 0.5 g's. After the ullage motors have reach full thrust, the S-IC retromotors and the first plane LSC are fired. When separation between the stages is approximately 6 feet, the S-II stage J-2 engines are ignited. Second plane separation occurs after the engines have reached full thrust. Physical separation of the interstage and the S-II occurs as the result of S-II stage acceleration and impingement of the J-2 exhaust on the aft interstage. Figure 14 depicts the time sequence of the separation.

Propellant Dispersion System

The function of the propellant dispersion system is to rupture the propellant tanks when the proper command is received by the destruct controller from the command destruct receiver. The system permits dispersal of propellants prior to impact if it is necessary for the Range Safety Officer to curtail the flight.

The system consists of the command destruct receivers (described with the RF systems), controllers, electronic bridge wire (EBW) firing units and detonators, a safe and arm device, confined detonating fuse (CDF) initiators and linear shaped charges (LSC).

The controller is a distributor for the signals from the command destruct receiver. The destruct signal is routed from the controller to the EBW firing unit and detonator. The system is redundant up to the safe and arm device. The safe and arm device is between the EBW detonator and the CDF. In the safe position it physically blocks the initiation shock wave from the CDF. In the arm position, the shock wave is transferred to the CDF train. The CDF initiators are also connected to the initiators in the S-IVB and S-IC stages so that if any of the three stages have activated the CDF, activation will be propagated to the other stages.

The CDF train, when initiated, cuts a slot in one side of the LH_2 tank and on the opposite side of the LOX tank. The train is located in the systems tunnel on the LH_2 tank and on the aft skirt structure just aft of the bolting ring for the LOX tank.

A block diagram of the system is given in Figure 15 and a schematic in Figure 16.

Flight Control System

The stage portion of the flight control system consists of the J-2 engine gimbal actuators, two for each of the four outboard engines, and the hydraulic system to drive the actuators, one for each of the four engines. The electro-hydraulic servo valves which control the actuators receive position signals from the instrument unit. Feedback for the valve itself is mechanical feedback of actuator piston position through a cam actuated mechanism to a torque summing device on the servo valves. A block diagram of the Flight Control System is given in Figure 17.

The actuators are piston type, linear, double acting units capable of delivering 42,000 pounds of force and of gimbaling the engines in a ±7° square at 8° per second. The servo valve is a proportional four-way, two-stage, flow control valve with the rate and direction of fluid flow proportional to the magnitude and direction of current flow in the control coil.

The hydraulic system consists of a main hydraulic pump driven from the LOX turbo-pump shaft, an electrically driven auxiliary pump, and an accumulator reservoir. The system is closed and is pre-pressurized by GN_2 prior to liftoff.

Prior to lift-off the auxiliary pumps are utilized to stabilize temperature in the system and for checkout. The main pumps are started with the LOX turbo-pump. A schematic of the hydraulic system is given in Figure 18.

Electrical Power System

The electrical power system consists of three 28-volt 25-ampere hour batteries, one 28-volt 35-ampere hour battery, three power transfer switches, an instrumentation bus, a main bus, an ignition bus, a recirculation bus, a heater bus and associated cabling. A block diagram of the system is given in Figure 19.

The batteries are silver-zinc cells and employ potassium hydroxide as an electrolyte. The power transfer switches (motor driven make-before-break type) transfer the power source from ground support equipment to the on-board batteries. Figure 20 depicts a typical battery bus system.

Electrical Control System

The electrical control system controls various stage systems. Most of its components, solenoids, switches etc., are integral with the related mechanical systems. The systems controlled are:

Propellant feed system
Propellant utilization system
Recirculation system
Pressurization system
Flight control system
Engine systems
Propellant depletion cutoff.

The electrical control system receives inputs from the stage switch selector, from GSE, and from various sensors in the mechanical systems. It controls the opening and closing of the propellant fill and drain valves and the engine prevalves, the setting of the propellant utilization valve, starting of the LH_2 recirculation pump, the opening and closing of recirculation valves, the flow of pressurizing gases to the propellant tanks, engine start and cutoff, and the hydraulic systems. Figure 21 is a block diagram of the electrical control system.

Instrumentation System

The instrumentation system includes transducers and signal conditioners. It senses vehicle performance parameters, conditions the outputs, and feeds the signals to the telemetry system. A typical flight stage has in excess of 800 transducers for in-flight measurements. Parameters measured include pressure, temperature, flow, vibration, noise, stage, acceleration and fluid level.

Radio Frequency Systems

The RF systems include the telemetry systems and the Range Safety Command system which provides the initiate signal for the propellant dispersal system.

The Range Safety Command system is a dual receiver system operating in the 400-450 MC band. The antenna system is an omni-directional system consisting of four linear cavity-backed slot antennas mounted flush to the skin of the forward skirt at 90° intervals.

The telemetry system will vary from flight to flight depending on requirements. Available are PCM/FM, FM/FM, PAM/FM and SS/FM transmitters. All operate in the 225-260 MC band. The systems are capable of transmitting various multiplexed combinations of continuous channels and commutated channels. The antenna system is similar to that of the Range Safety Command system. Up to four telemeters can be multiplexed on one antenna system. When more than four transmitters are carried, a second omni-directional antenna system is added. Figure 22 is a block diagram of a typical stage RF system.

Conditioning and Thermal Control Systems

These systems consist of the LH_2 and LOX purging systems, LH_2 tank pre-conditioning system, thermal conditioning for various equipment containers, and the engine compartment conditioning system. All are active only during prelaunch countdown.

The LH_2 and LOX tanks and various plumbing and valves are purged during prelaunch checkout by gaseous helium or nitrogen prior to loading of LOX or LH_2. This is done to remove moisture and contaminants from the system.

In order to minimize structural stresses, the LH_2 tank is chilled down to -50°F in the vicinity of the bolting ring before completing LOX loading and to -160°F before commencing LH_2 loading. This is accomplished by GH_2 supplied from GSE.

Conditioning and purging of the engine compartment is accomplished by introducing warm nitrogen from GSE into the area through a 13 inch feed line. The nitrogen is distributed through a 10 inch orificed manifold and escapes through vent holes in the skin of the aft skirt and aft interstage. Figure 23 is a sketch of the system.

The thermal conditioning system maintains temperature control of the various equipment containers in the engine compartment and the forward skirt volume. Prior to cryogenic loading, a continuous flow of ambient air is provided from GSE to a distribution manifold and through the containers. After cryogenic loading, warm nitrogen is provided. Figure 24 is a sketch of the system for equipment containers in the engine compartment. Figure 25 is a sketch of a typical container.

Leak Detection and Purge Systems

The leak detection and purge system is used during prelaunch countdown to verify the integrity of the LH_2 tank, insulation on the LH_2 tank, including the sidewalls, common bulkhead and forward bulkhead, and seals and joints in the LH_2 and LOX systems. The system is also utilized to purge leakage of hydrogen from the stage systems or air from the atmosphere which might cause explosive conditions or deterioration of the insulation. The system includes an evacuation mode which is used continuously during detanking operations to prevent pressure buildup of entraped gases in the core of the common bulkhead or in the LH_2 tank insulation.

In the purge mode, gaseous helium is circulated in sufficient quantity to purge or dilute leakage which may occur from the propellant systems or from the atmosphere through the insulation. In the leak detection mode, gaseous nitrogen is circulated through the system and samples are bled off to a gas analyzer. If detectable quantities of hydrogen, oxygen or air appear in the sample, the area which is leaking can be isolated by using various combinations of valve settings. Figure 26 is a block diagram of the system.

Figure 27 is a sketch of the portion of the system used for the LH_2 tank sidewall insulation. Figure 28 is a sketch of the portion of the system used for the common bulkhead. Figure 29 is a sketch of a typical implementation of the system for flanges and seals. There are 432 of these joints on each stage.

T. H. Crowe

1024-THC-jvd

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Attachment
Figures 1 thru 29

Copy to
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2. Model Specification J-2 Rocket Engine, Rocketdyne, 7/20/60.

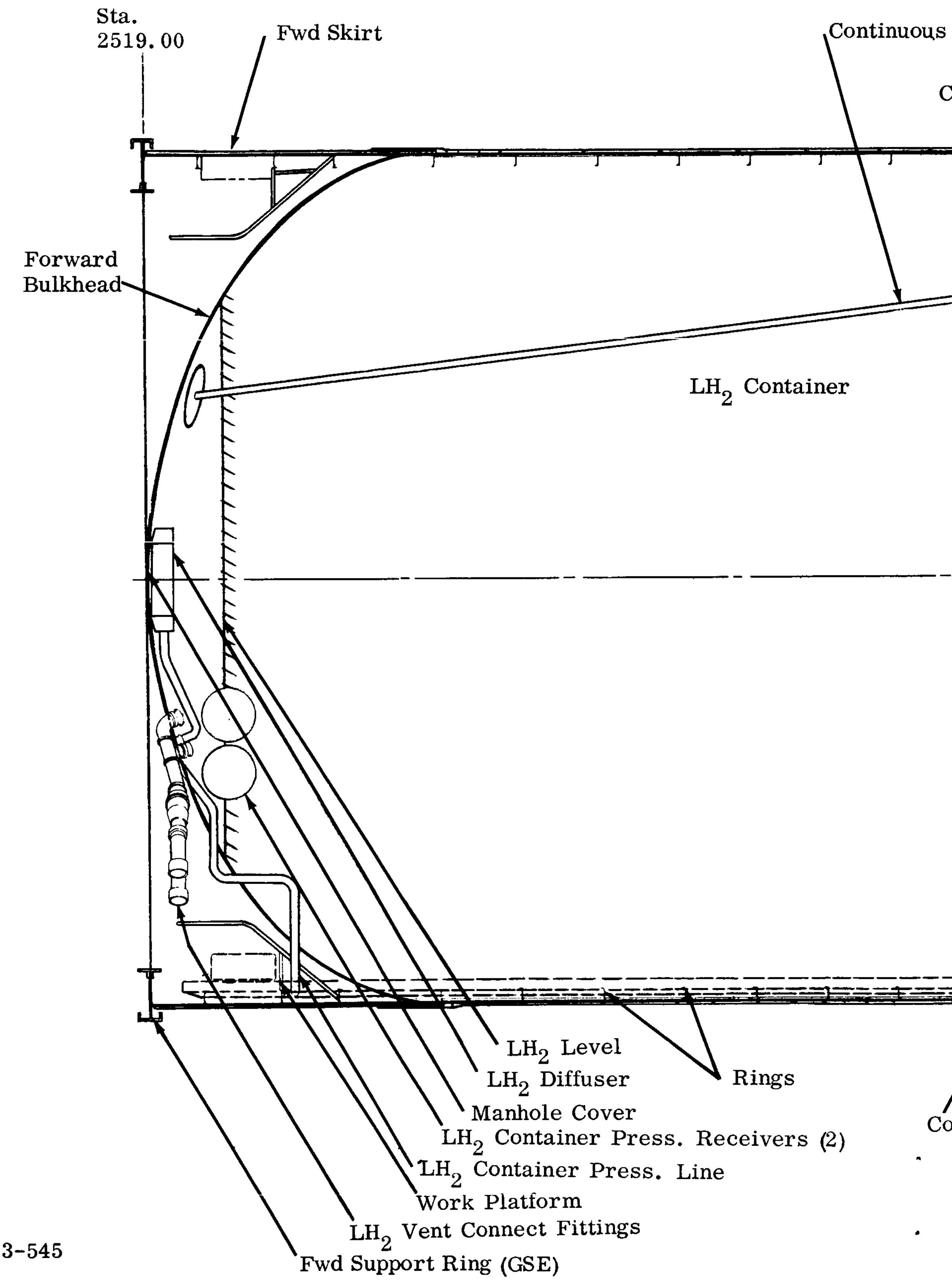
3. Saturn S-II General Manual, NAA SM-S-II-01, 10/1/64.

4. S-II Von Braun Briefing, NAA SP64-24, 2/64.

5. Saturn S-II Quarterly Reviews 1 through 4, NAA, 1963 to 1967.

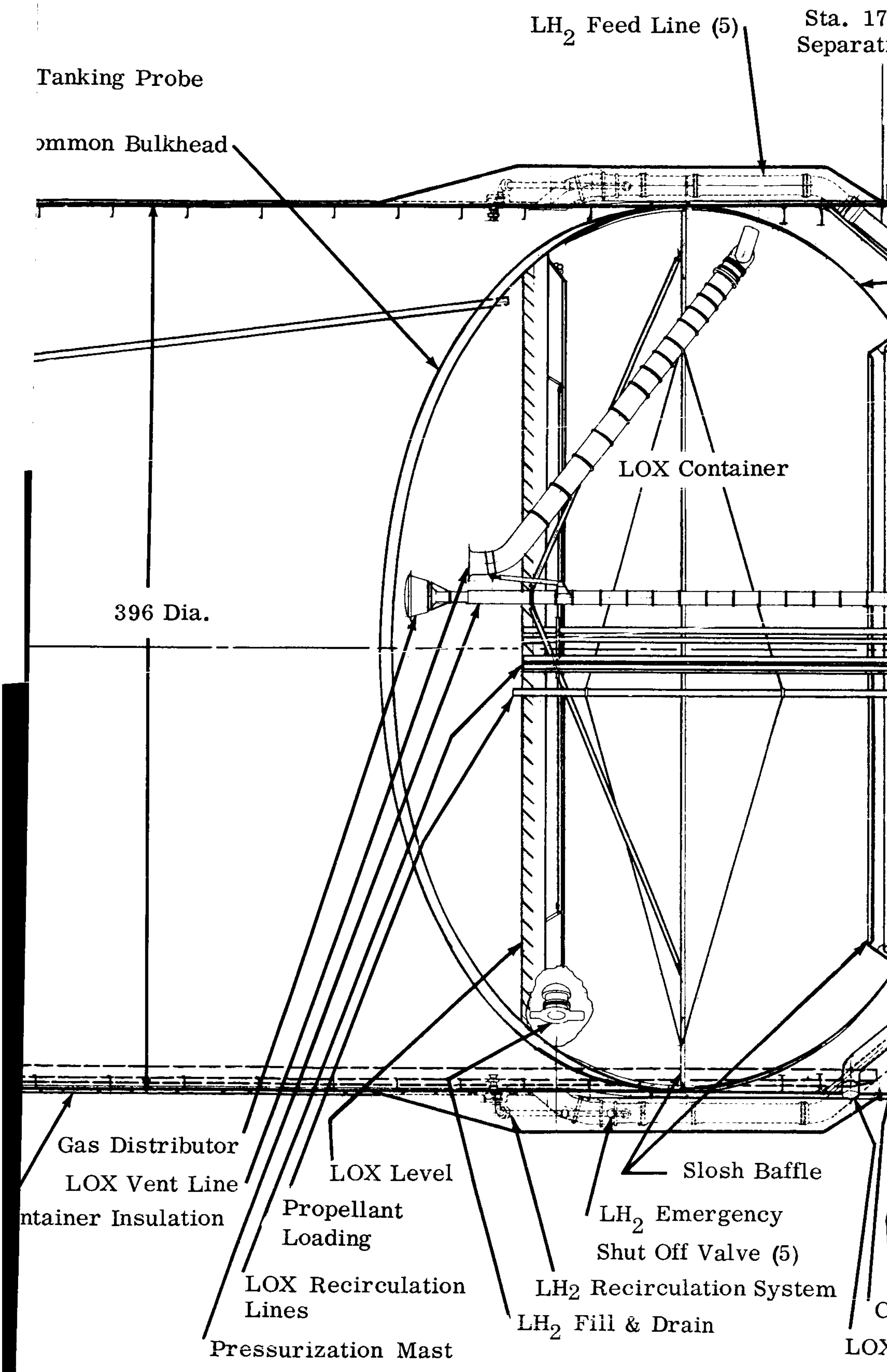
6. Saturn V PDP, MSFC, 8/65.

7. Saturn S-II Systems and Associated GSE Familiarization, NAA ST66-18, 12/66.



Sta.
2519.00
Fwd Skirt
Continuous
C
Forward
Bulkhead
LH_2 Container
LH_2 Level
LH_2 Diffuser
Rings
Manhole Cover
Co
LH_2 Container Press. Receivers (2)
LH_2 Container Press. Line
Work Platform
LH_2 Vent Connect Fittings
Fwd Support Ring (GSE)

3-545


LH$_2$ Feed Line (5)
Sta. 17
Separat
Tanking Probe
ommon Bulkhead
LOX Container
396 Dia.
Gas Distributor
LOX Vent Line
ntainer Insulation
LOX Level
Propellant Loading
Slosh Baffle
LH$_2$ Emergency Shut Off Valve (5)
LOX Recirculation Lines
LH$_2$ Recirculation System
LH$_2$ Fill & Drain
Pressurization Mast
LOX

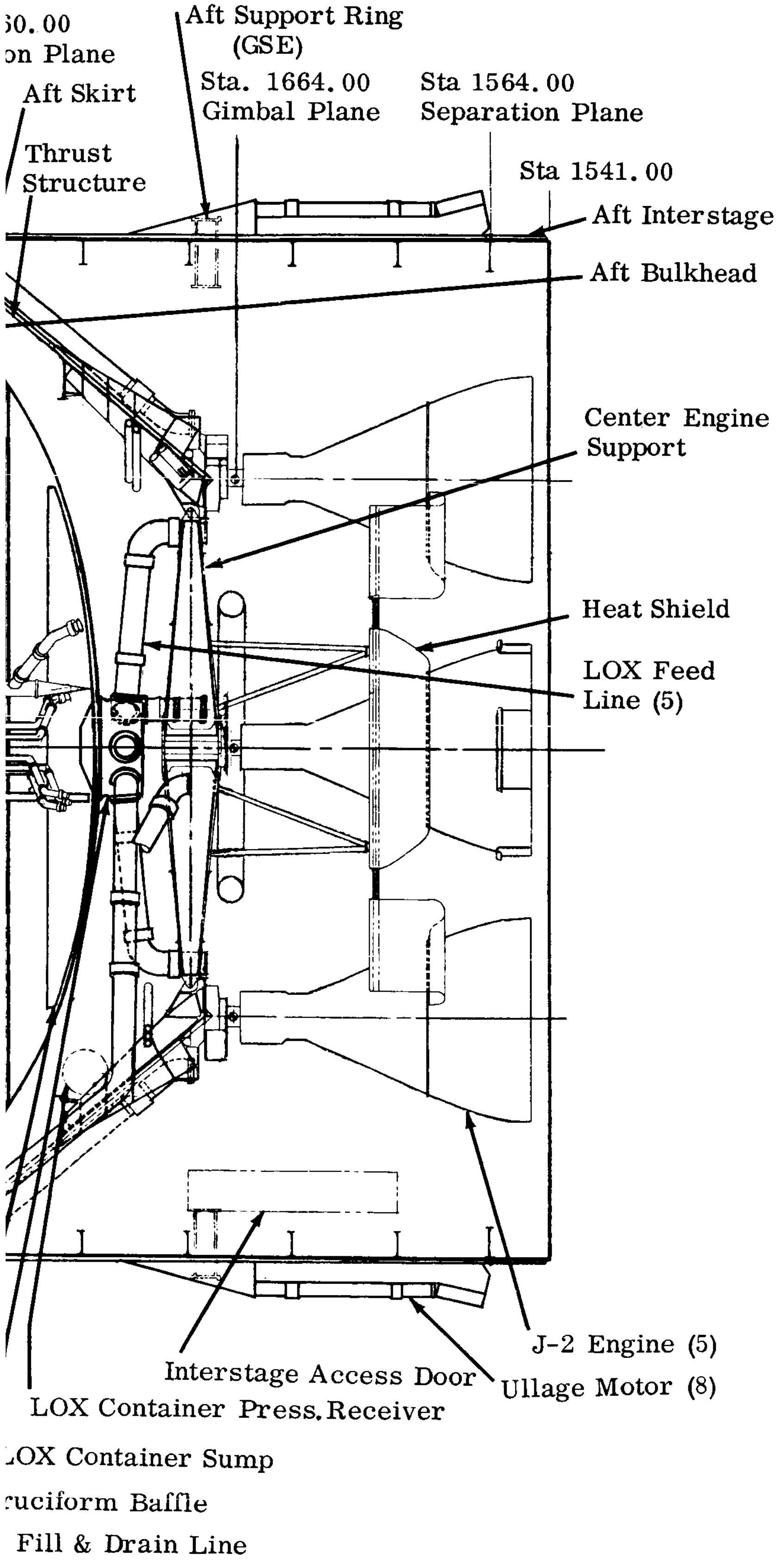


FIGURE 1 - S-II INBOARD PROFILE

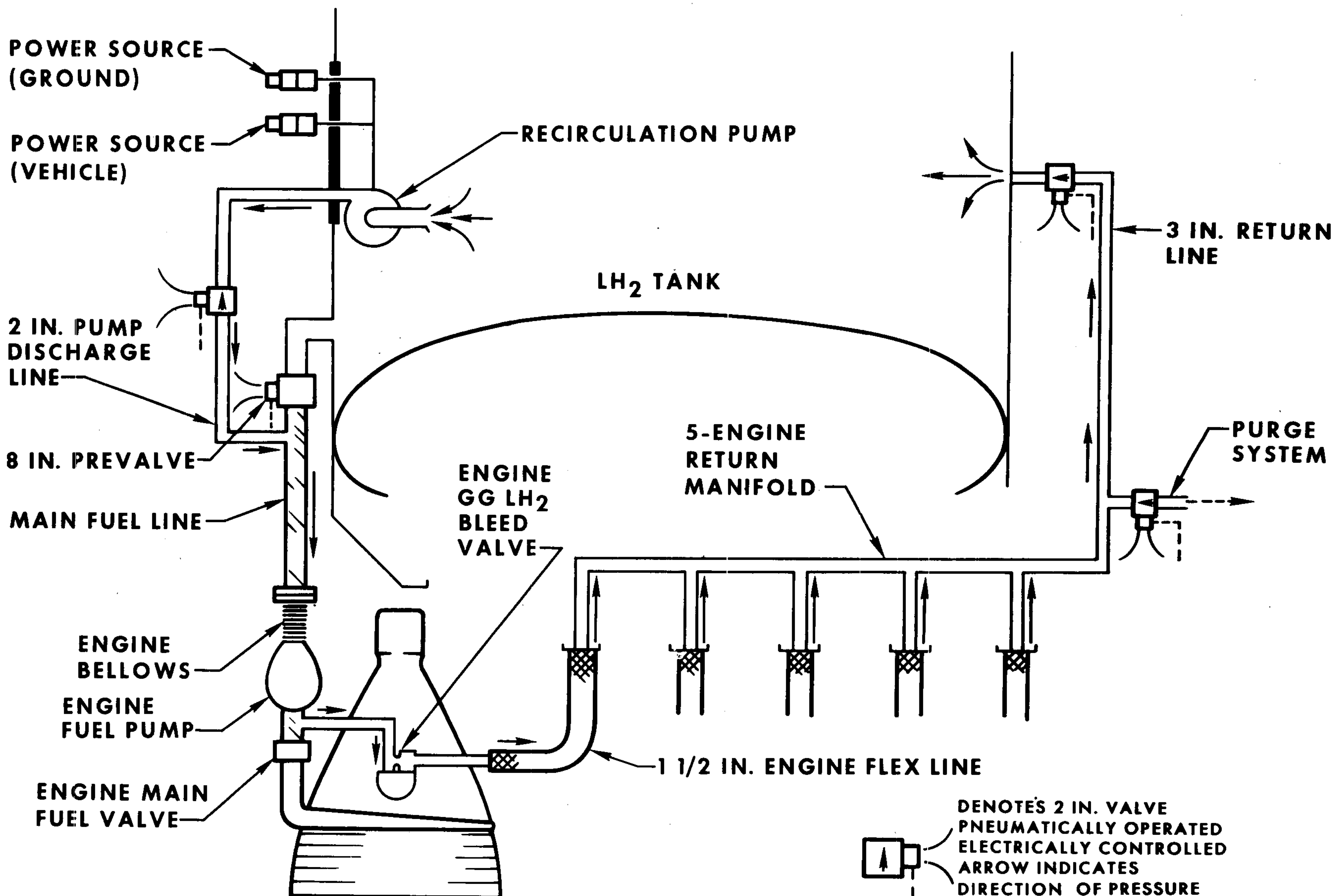


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FIGURE 2 - LH_2 RECIRCULATION SYSTEM

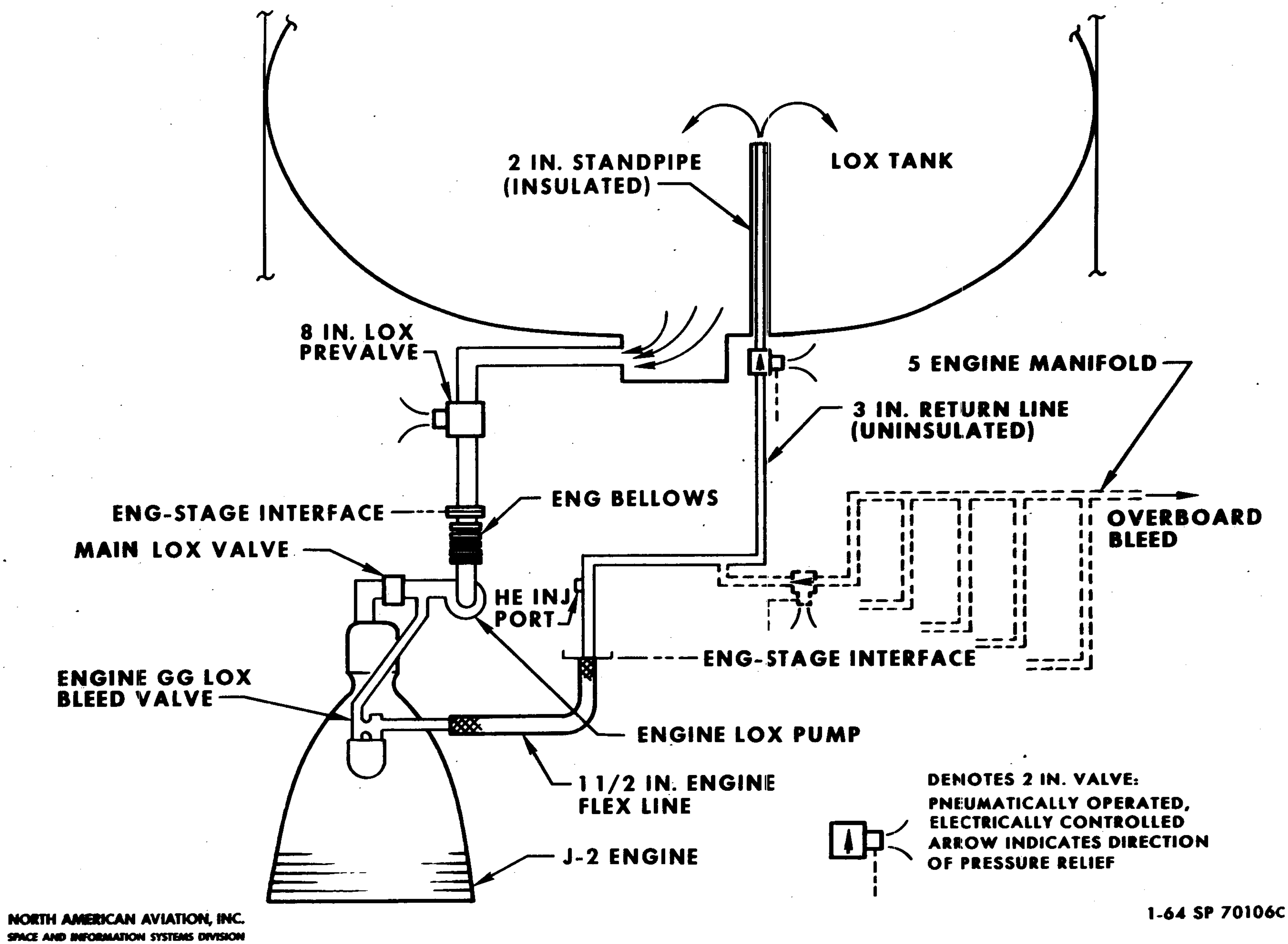

FIGURE 3 - LOX RECIRCULATION SYSTEM

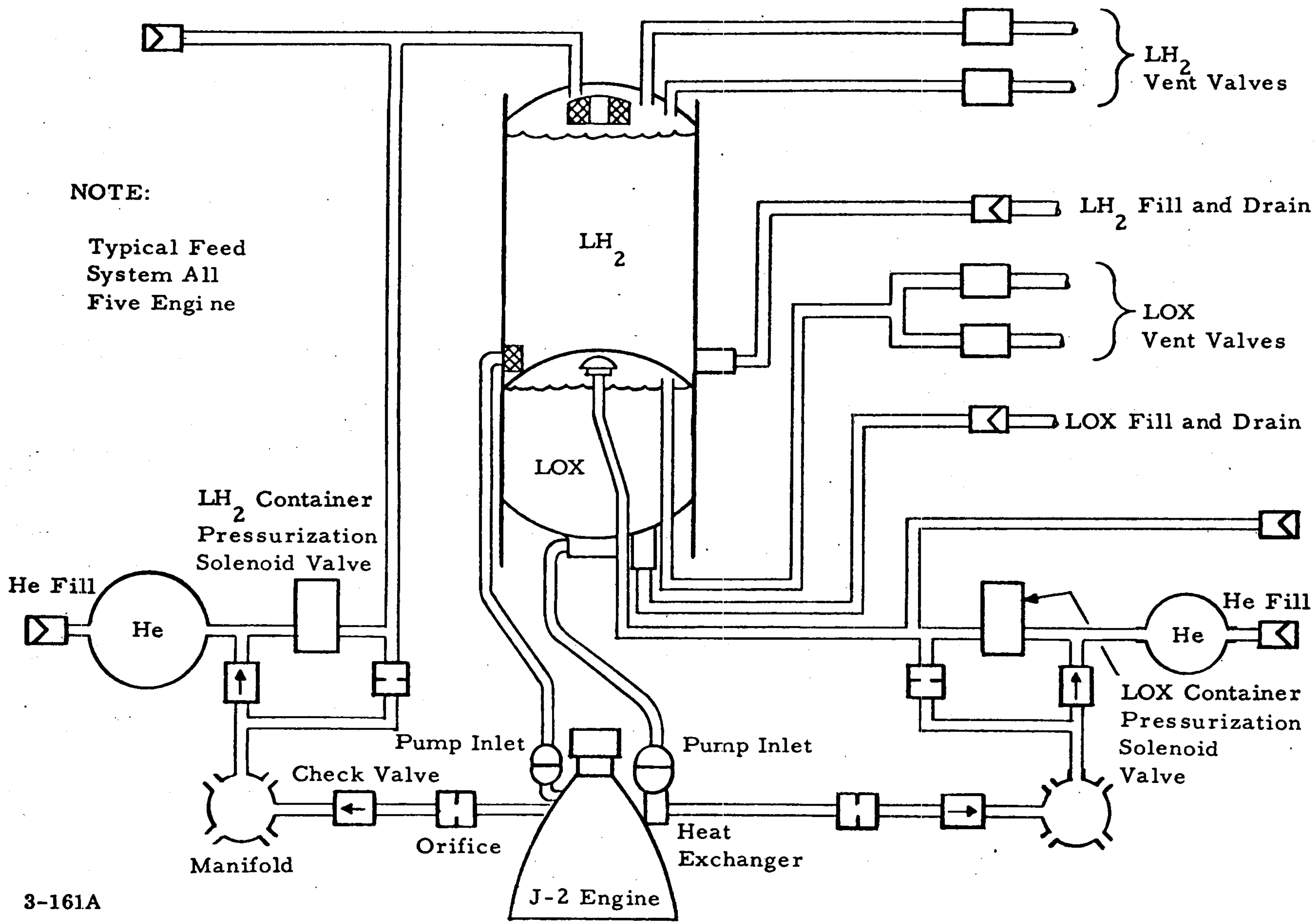

FIGURE 4 - PROPELLANT FEED SYSTEM S-II

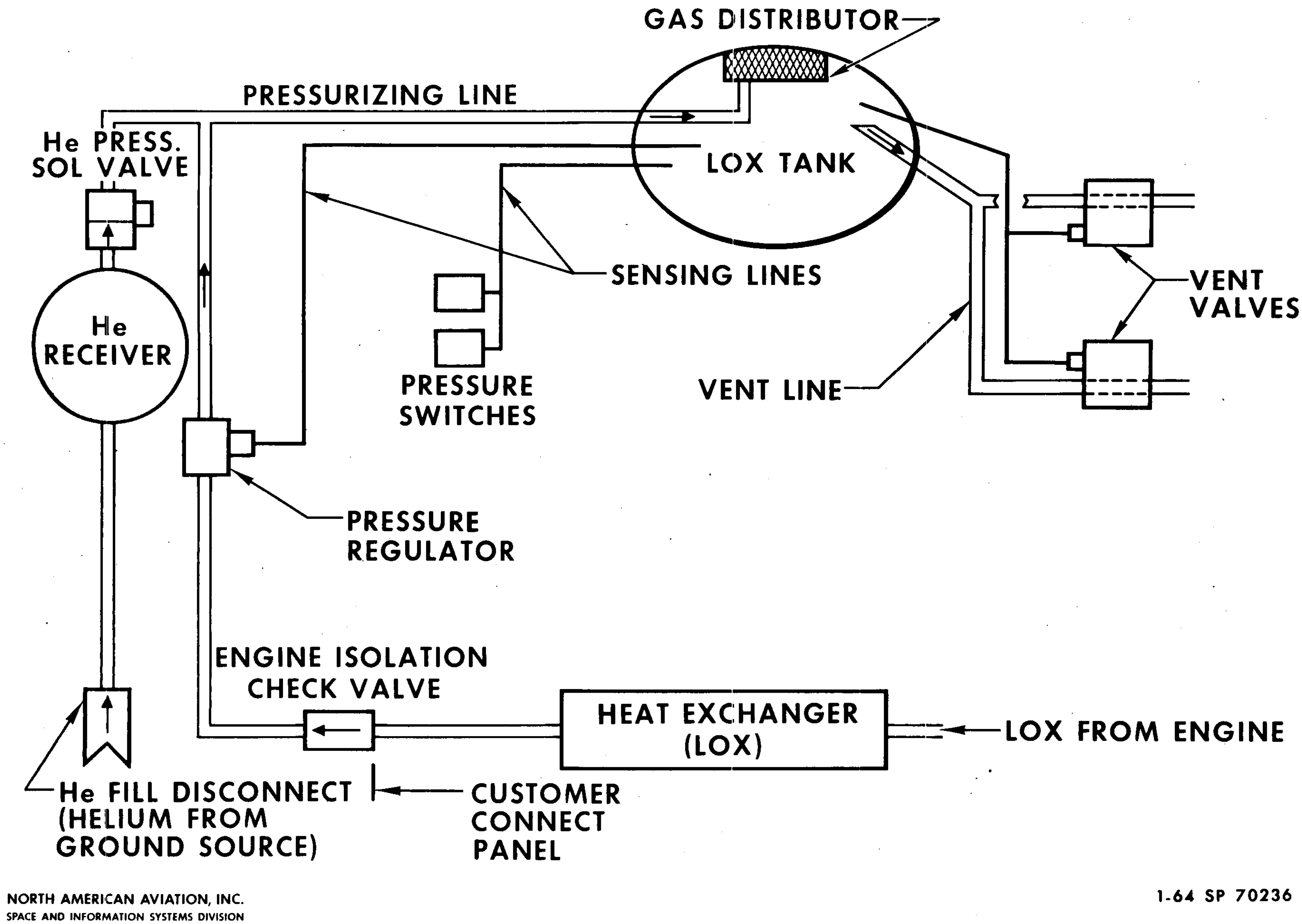

FIGURE 5 - LOX PRESSURIZATION SYSTEM

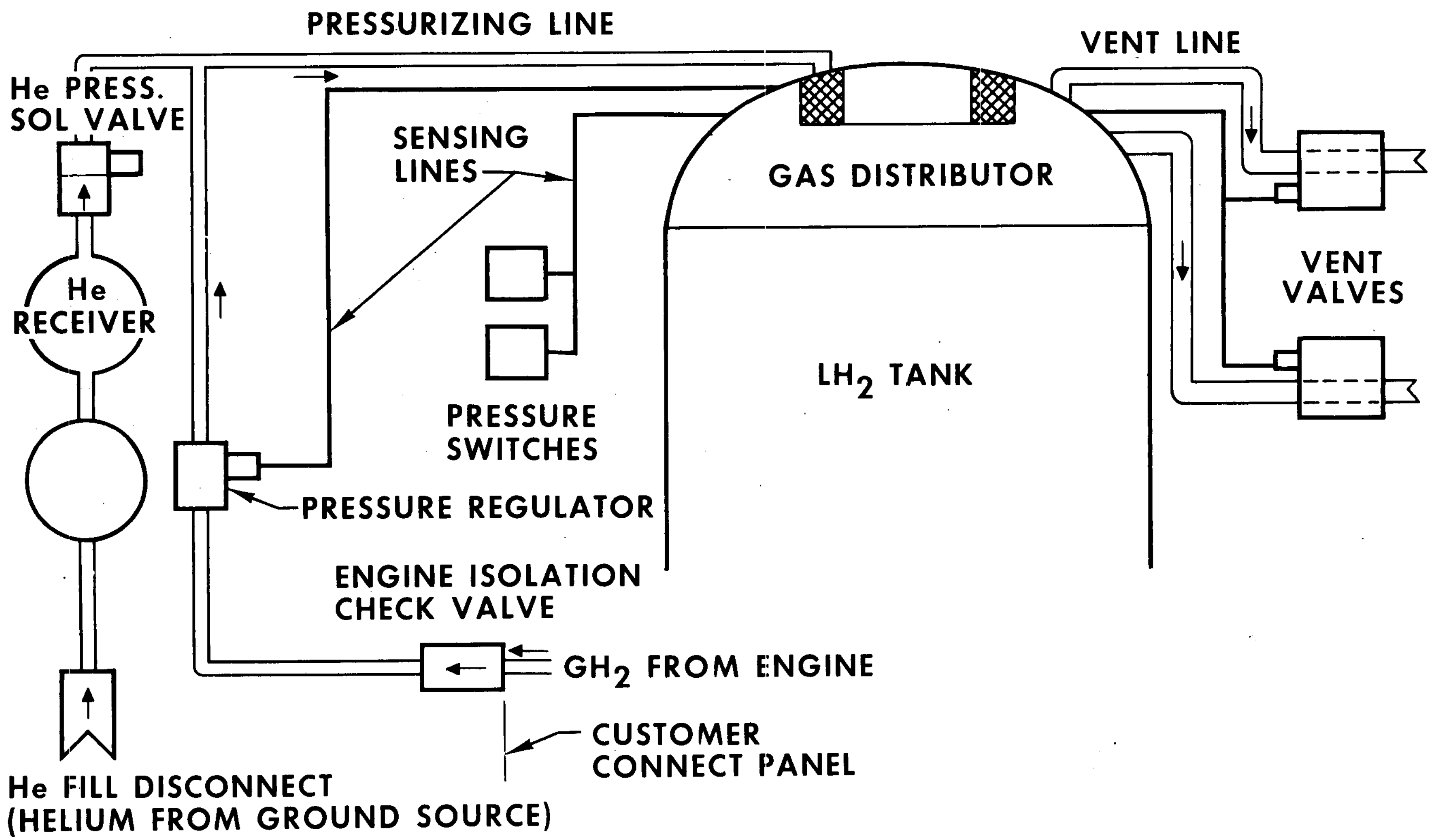

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FIGURE 6 - LH_2 PRESSURIZATION SYSTEM

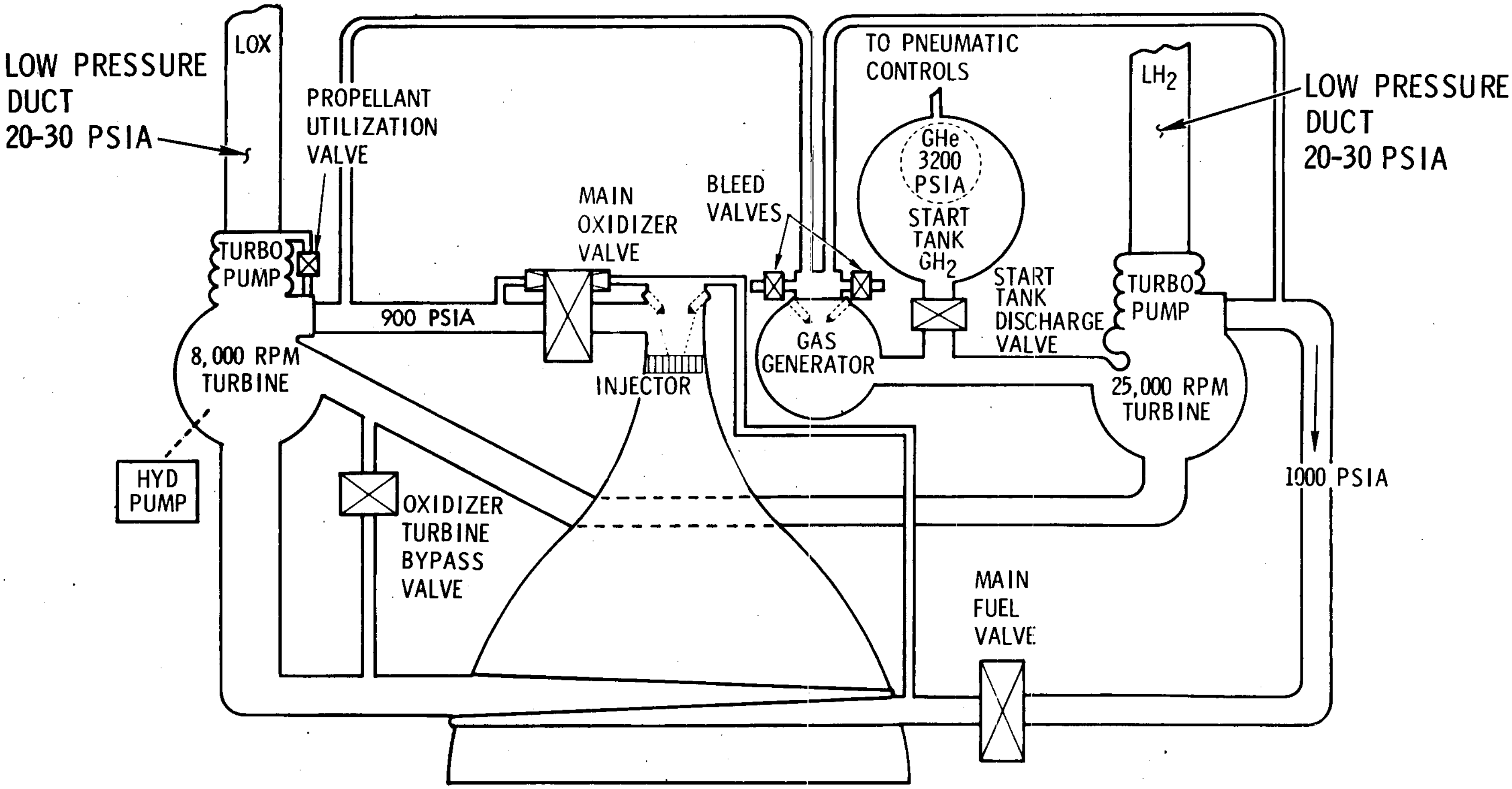

FIGURE 7 - SIMPLIFIED J-2 ENGINE SYSTEM

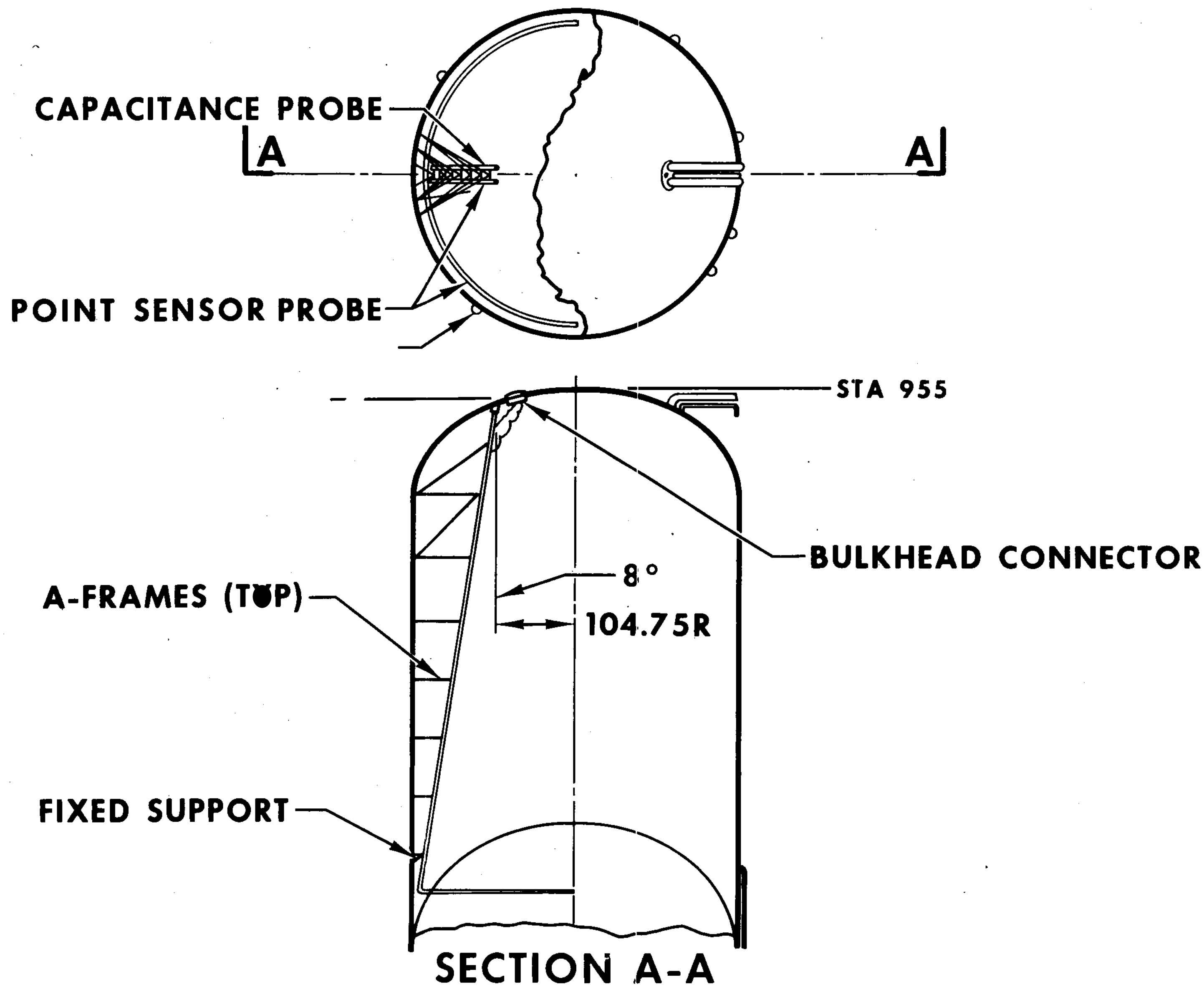

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FIGURE 8 - LH_2 TANK INSTALLATION

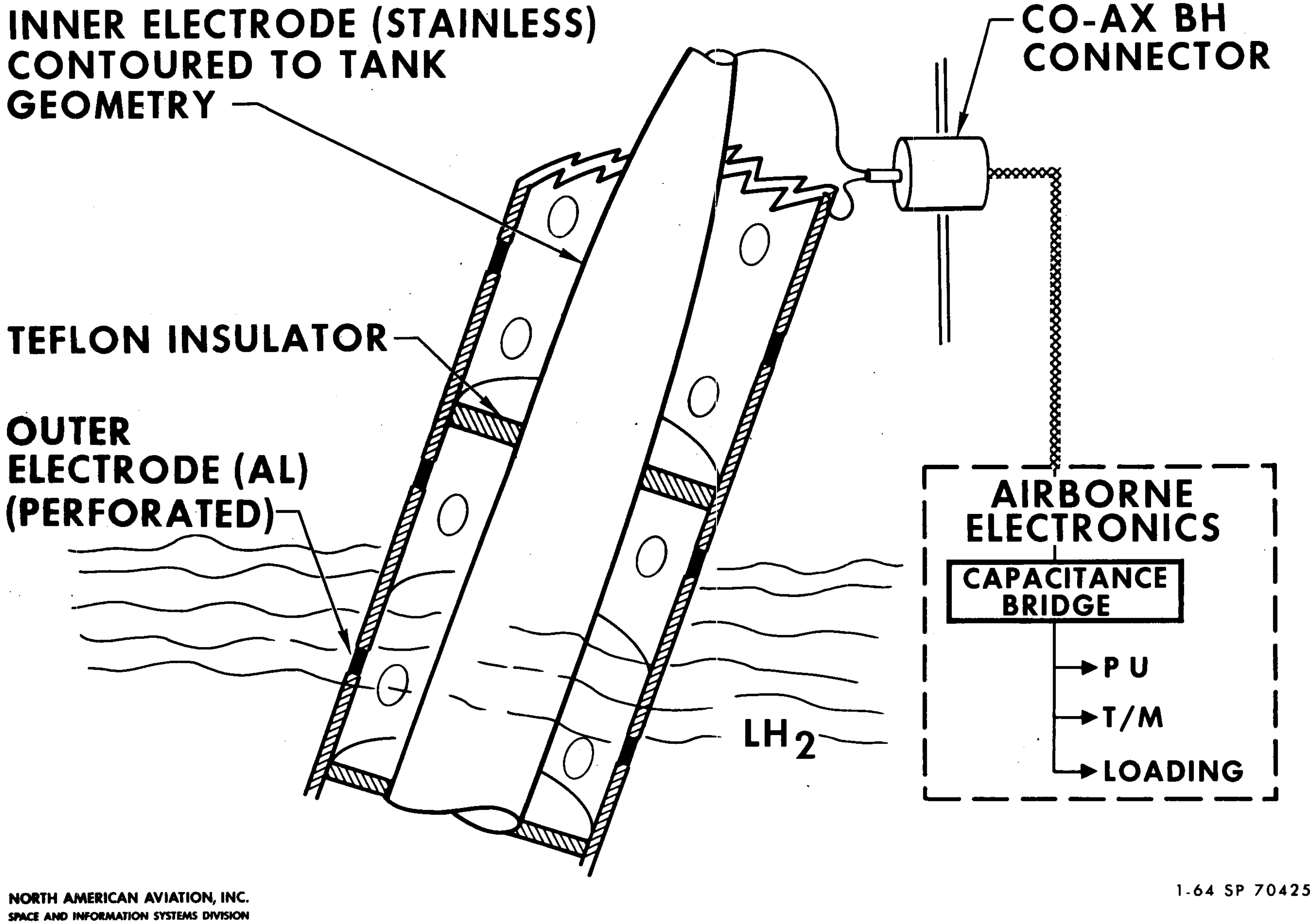

FIGURE 9 - LH_2 CAPACITANCE PROBE

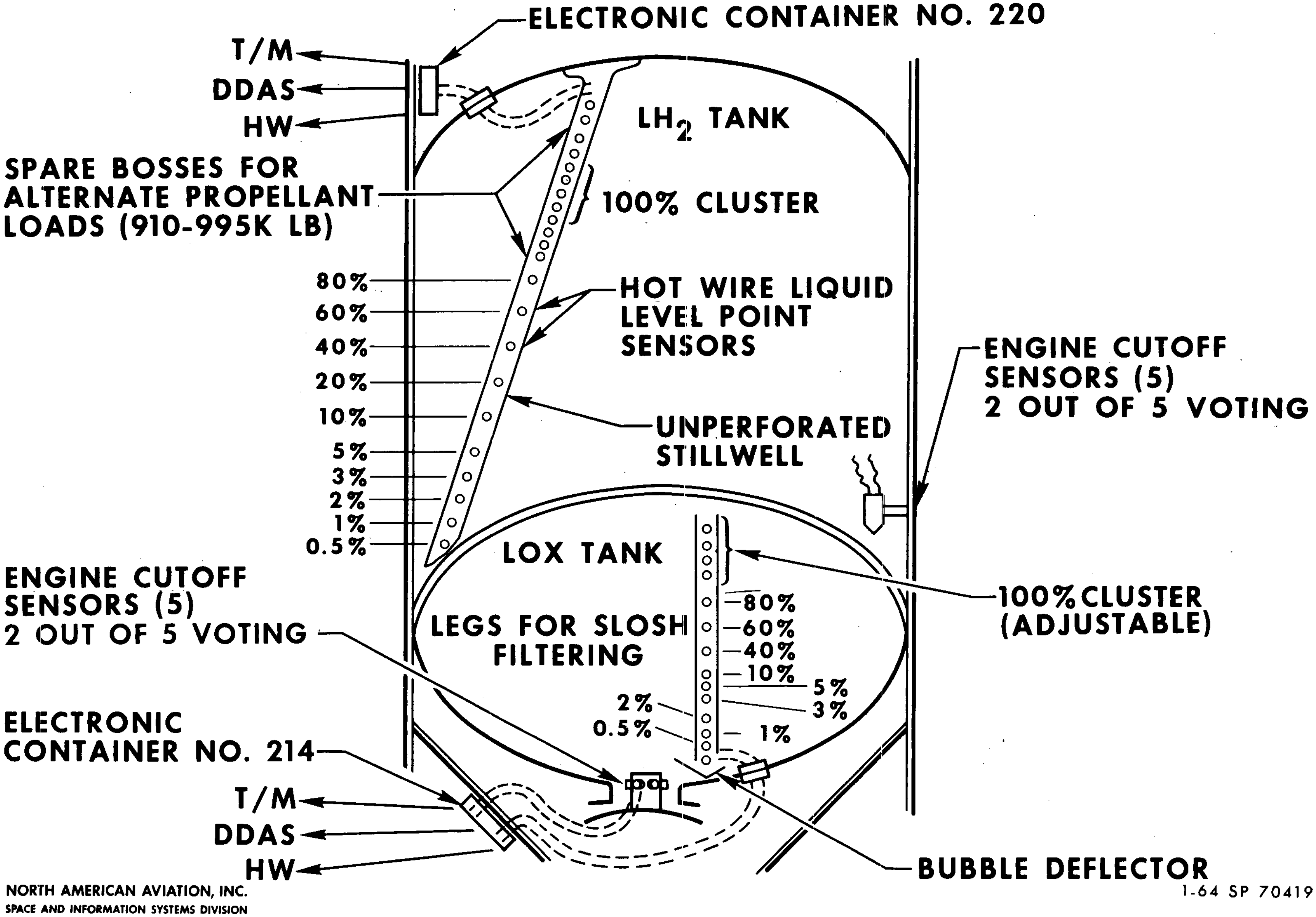

FIGURE 10 - POINT SENSOR SYSTEM - SCHEMATIC

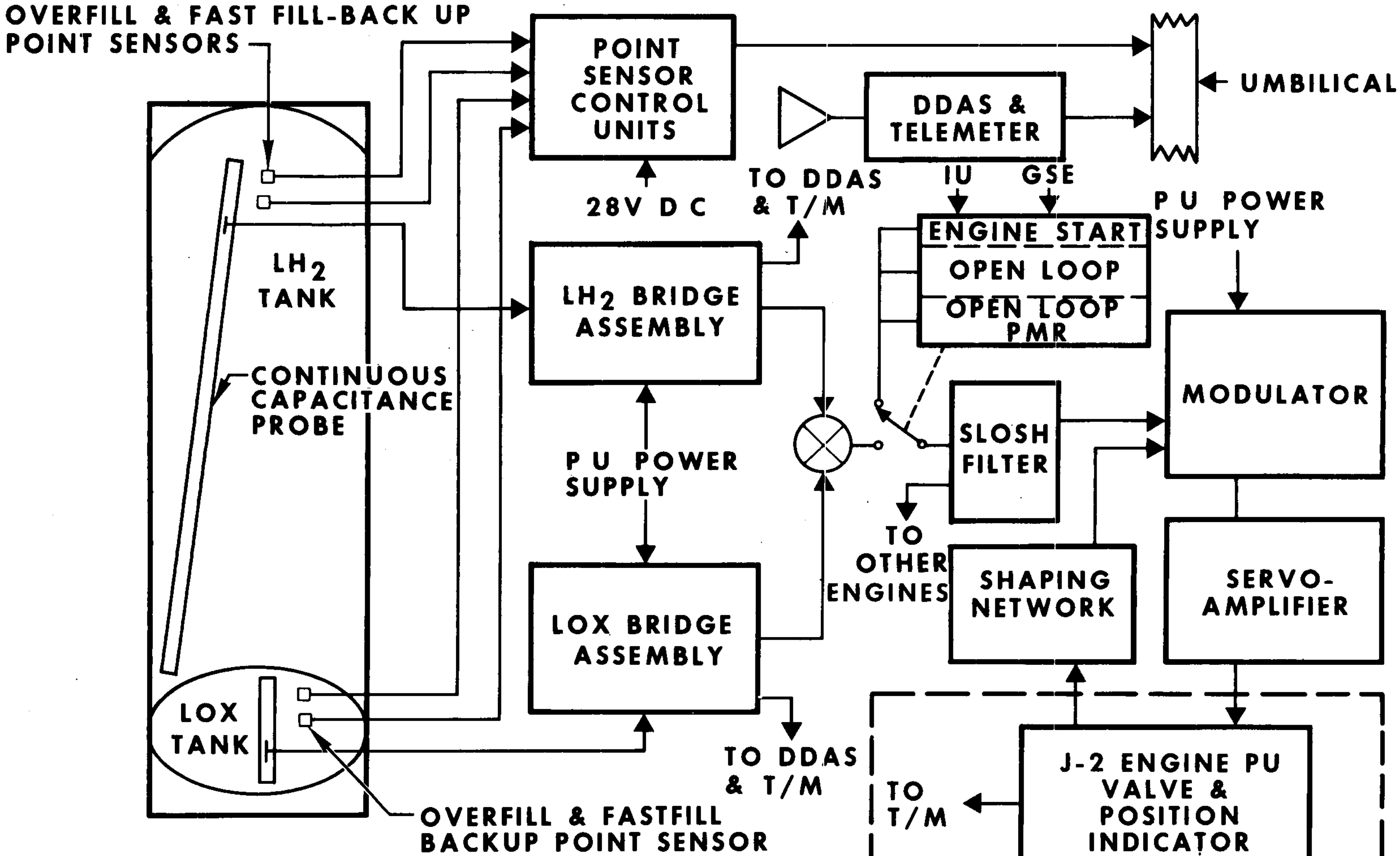

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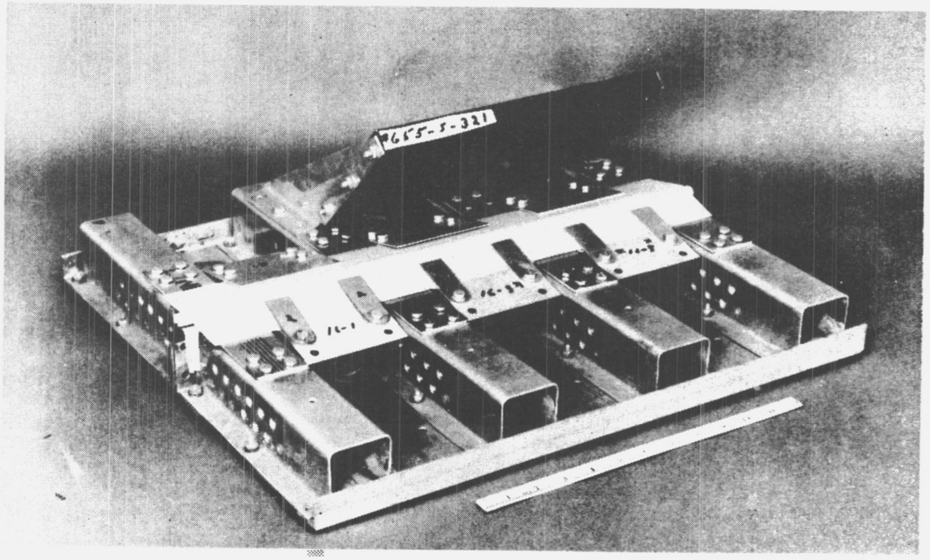
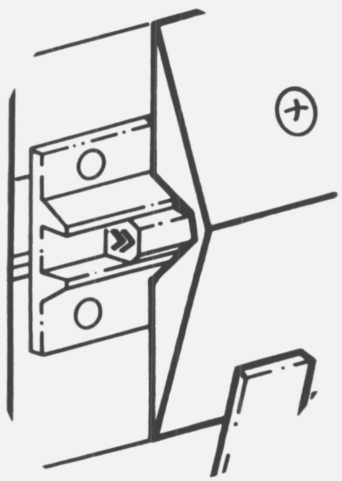
FIGURE 11 - PROPELLANT UTILIZATION, LOADING & MASS INDICATION SYSTEM - SCHEMATIC



TEST STRUCTURE



VIEW A

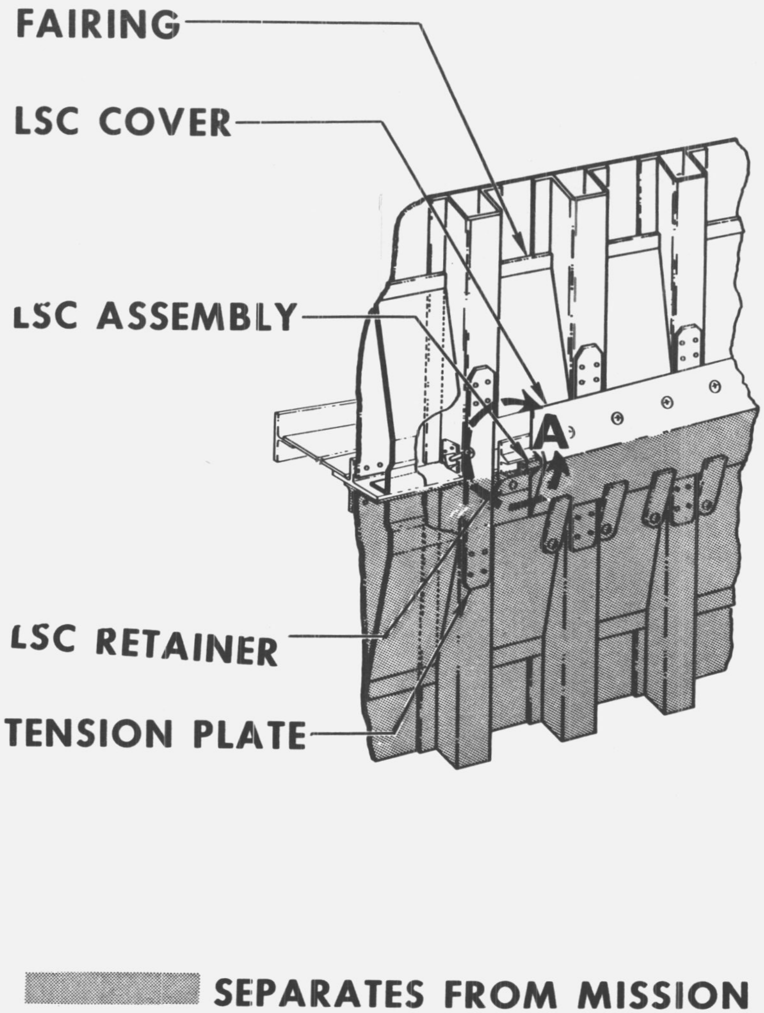


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FIGURE 12 - SEPARATION JOINT

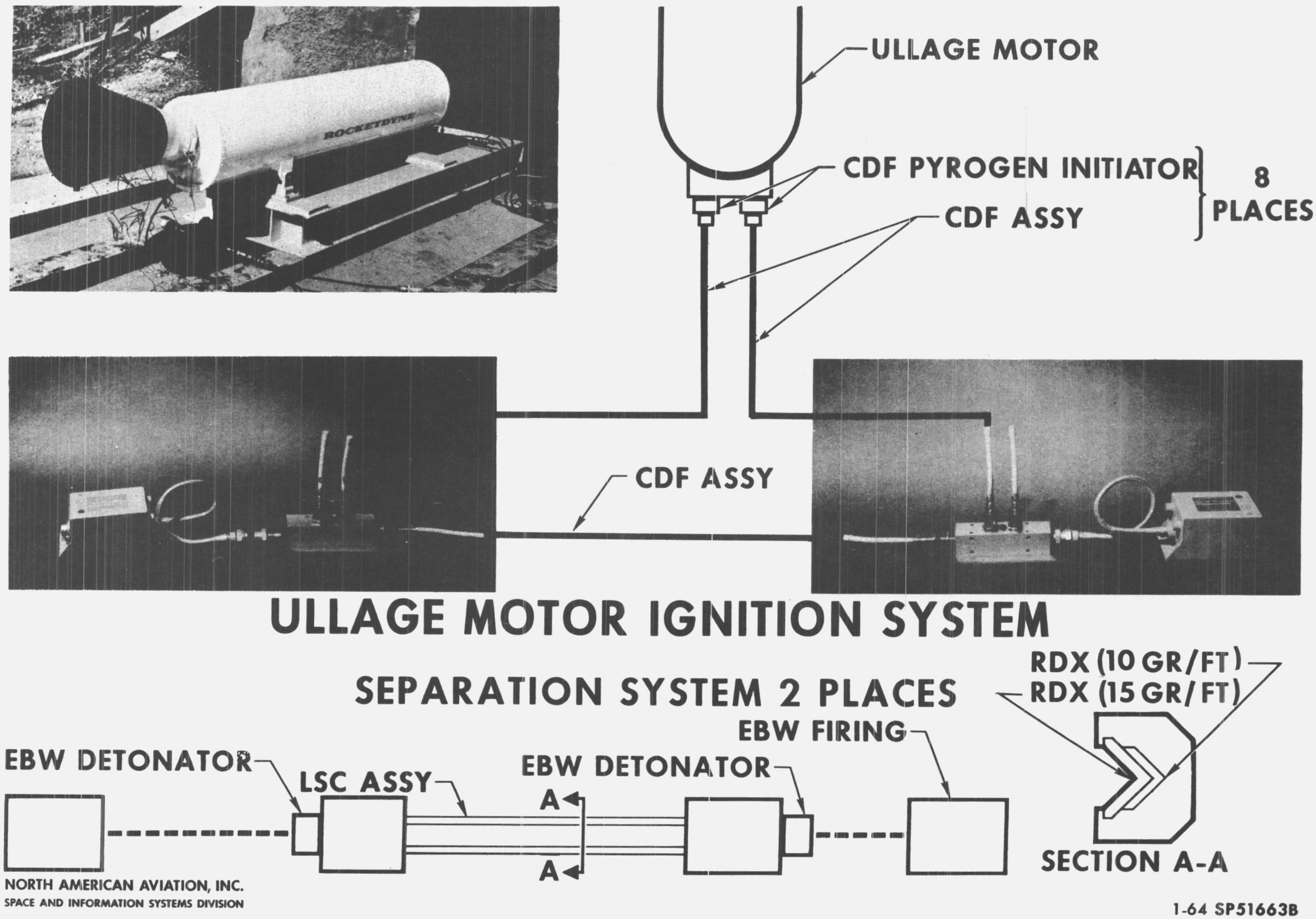

FIGURE 13 - SYSTEM SCHEMATIC

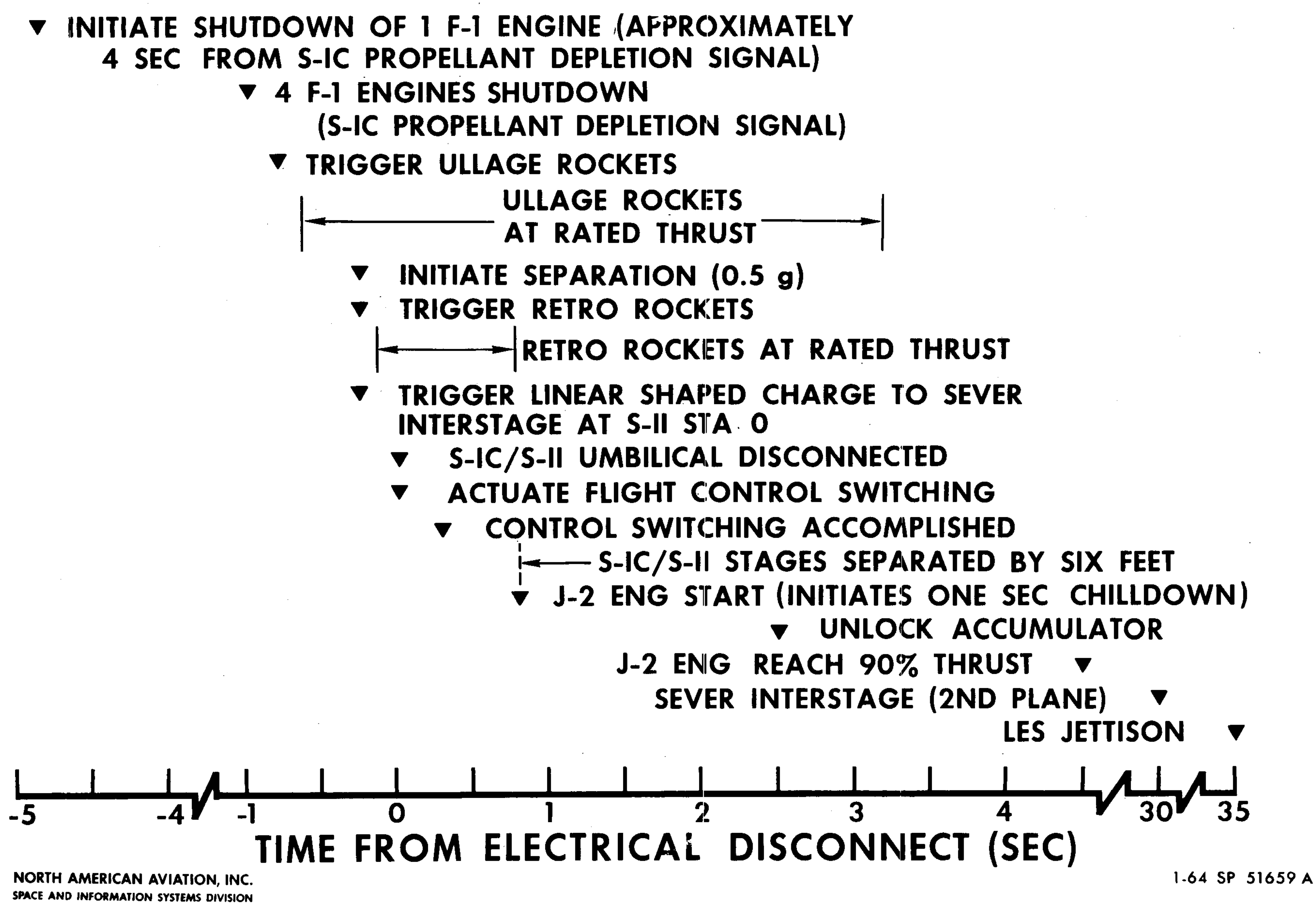

FIGURE 14 - SEPARATION SYSTEM SEQUENCE

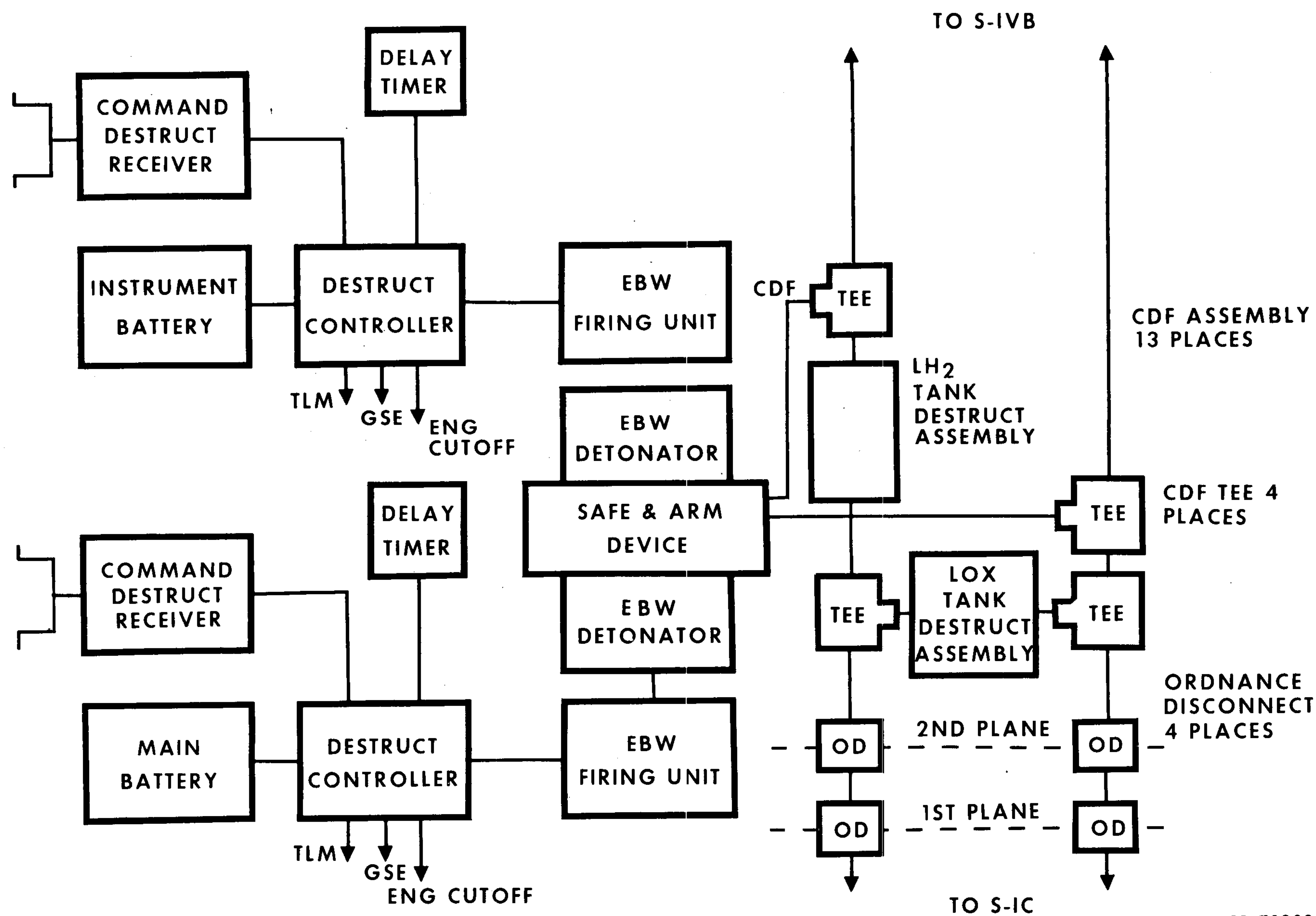

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FIGURE 15 - S-II PROPELLANT DISPERSION SYSTEM

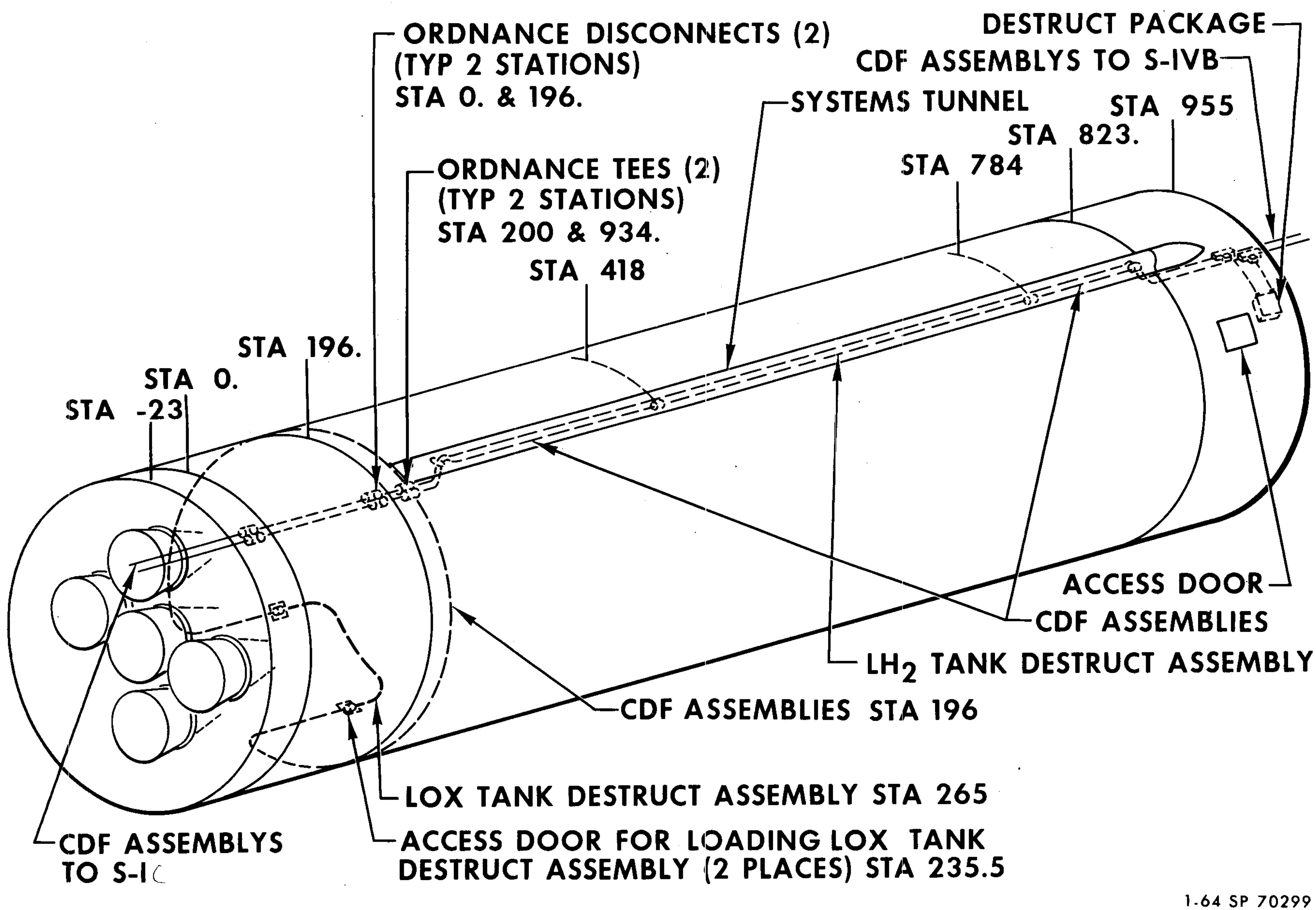

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FIGURE 16 - S-II PROPELLANT DISPERSION SYSTEM

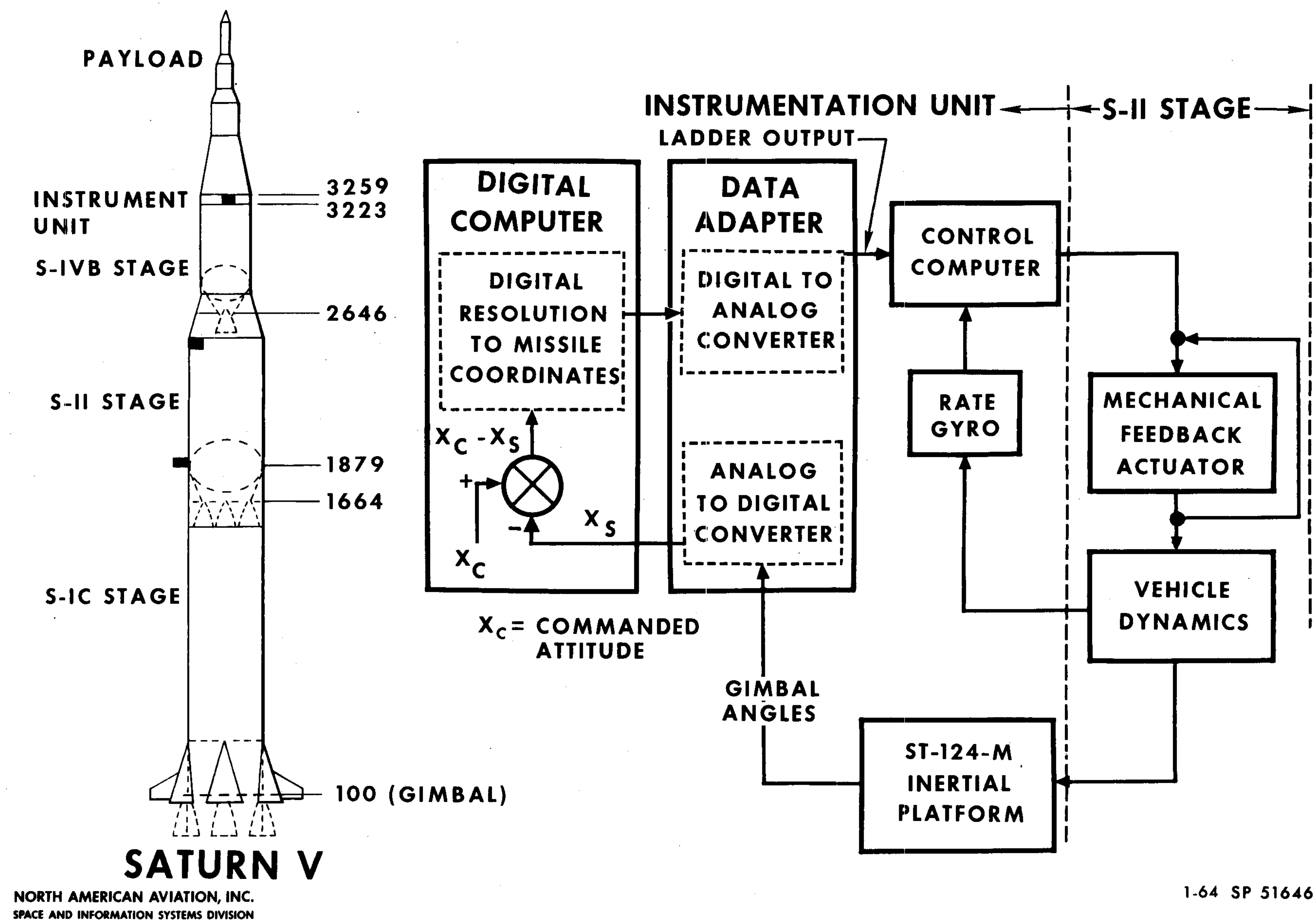

FIGURE 17 - FLIGHT CONTROL SYSTEM BLOCK DIAGRAM

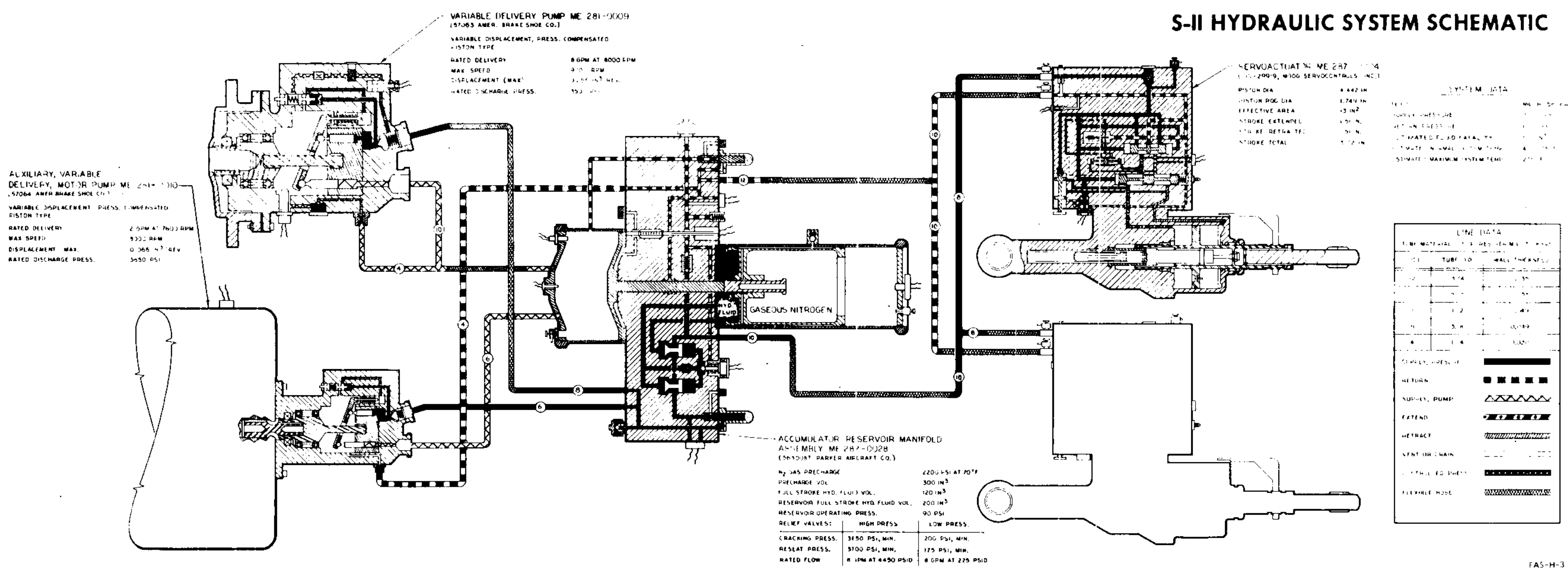

FIGURE 18 - S-II HYDRAULIC SYSTEM SCHEMATIC

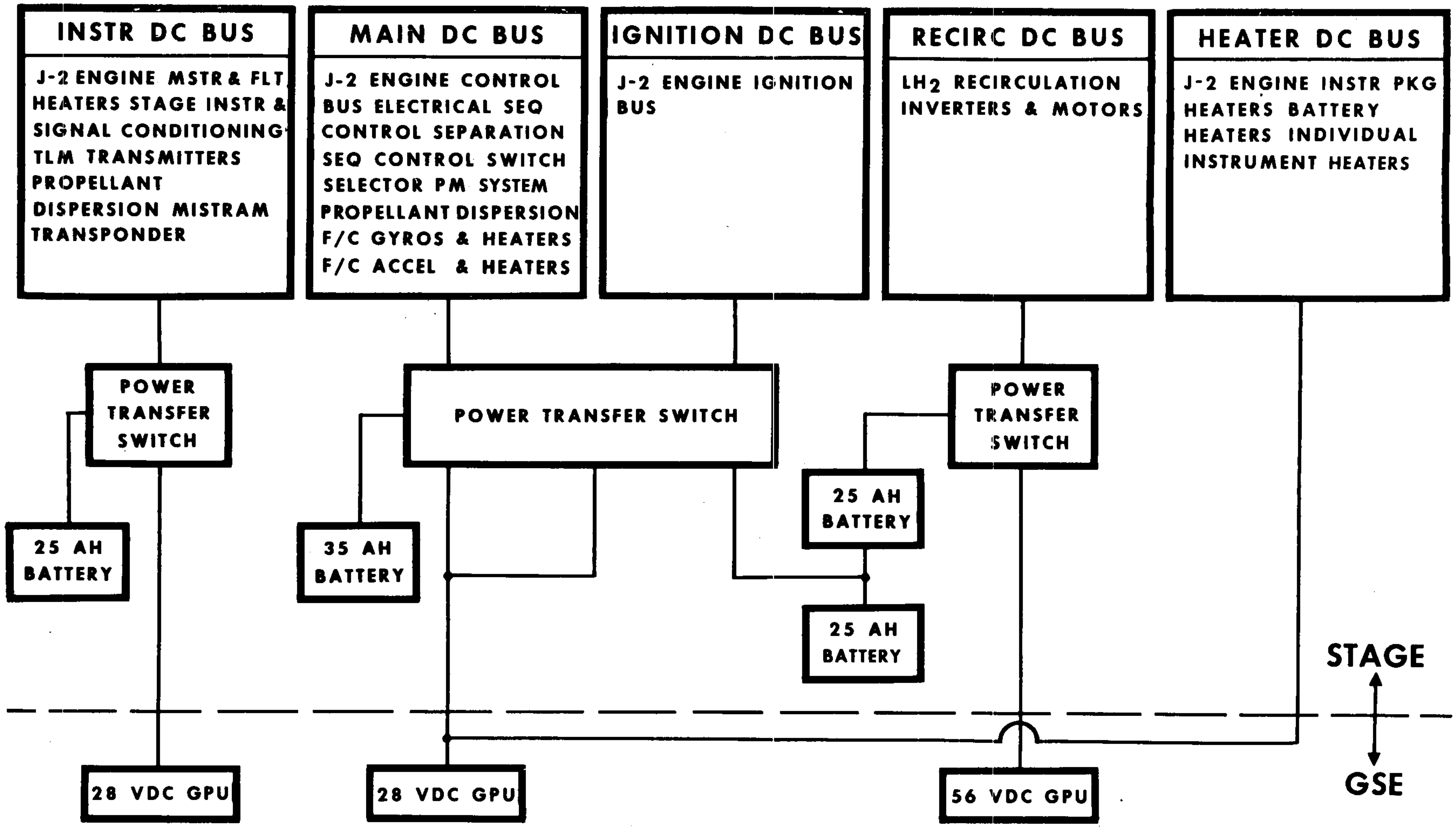

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FIGURE 19 - ELECTRICAL POWER SYSTEM BLOCK DIAGRAM

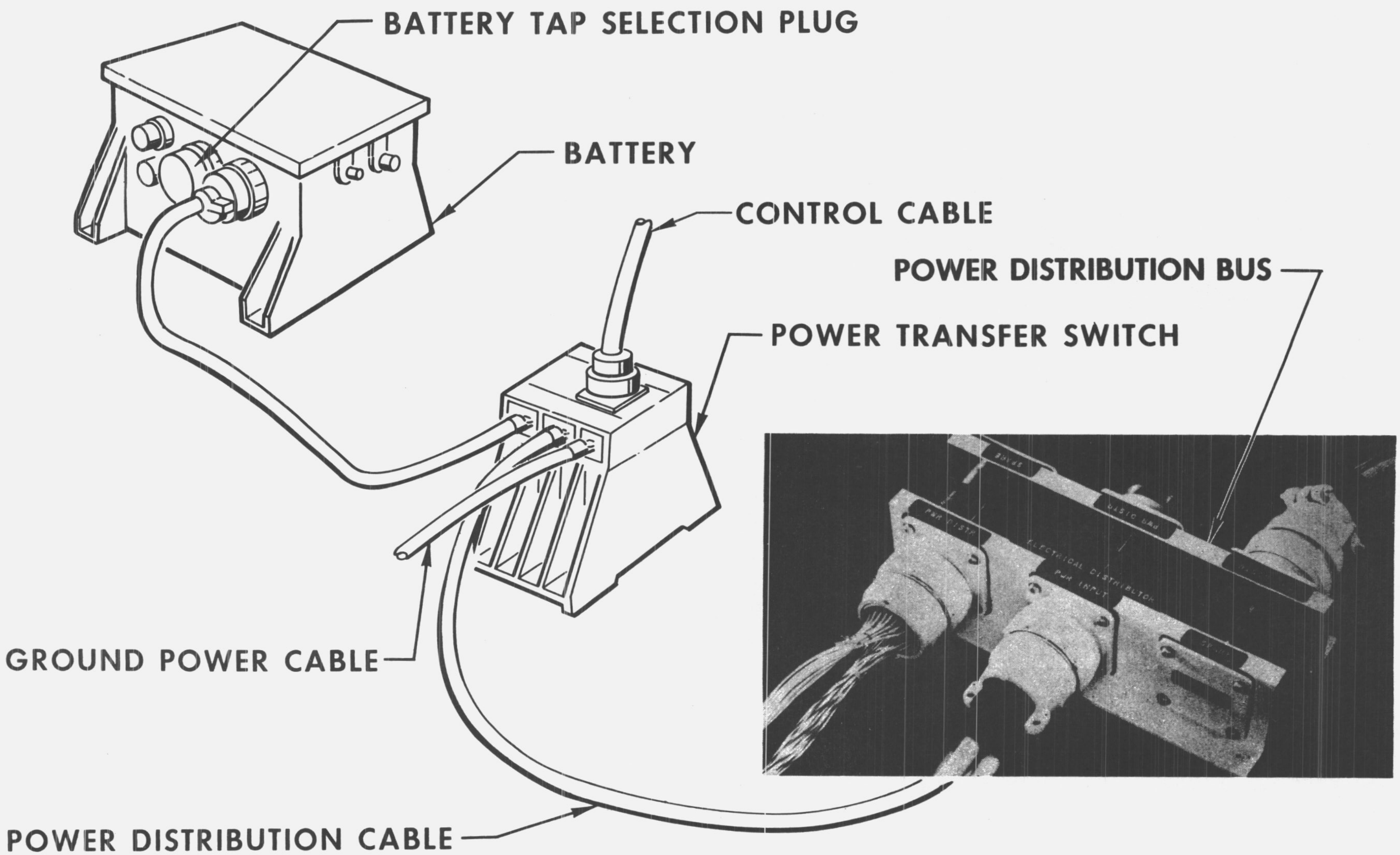

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FIGURE 20 - TYPICAL BATTERY - BUS SYSTEM

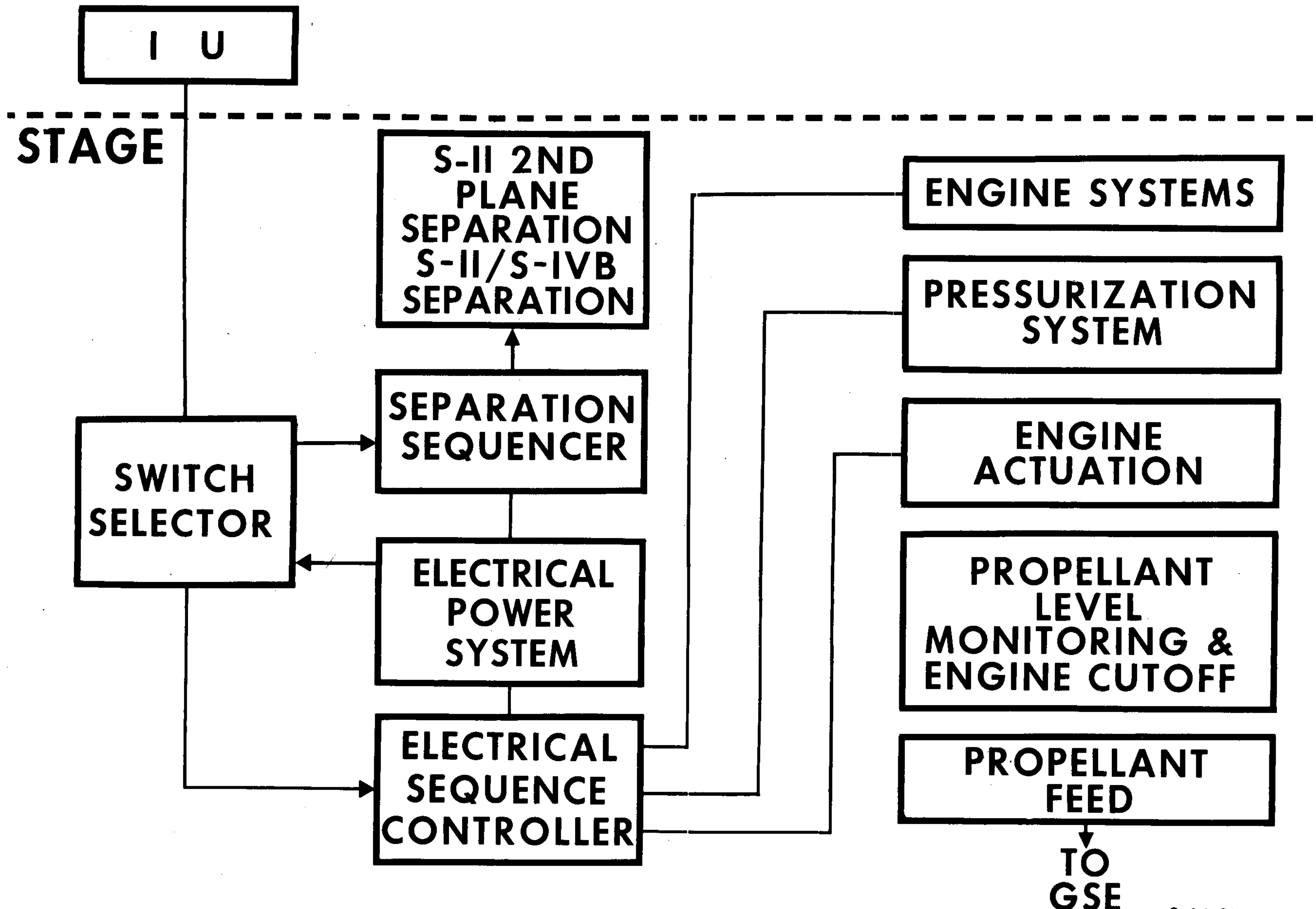

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FIGURE 21 - ELECTRICAL CONTROL SYSTEM

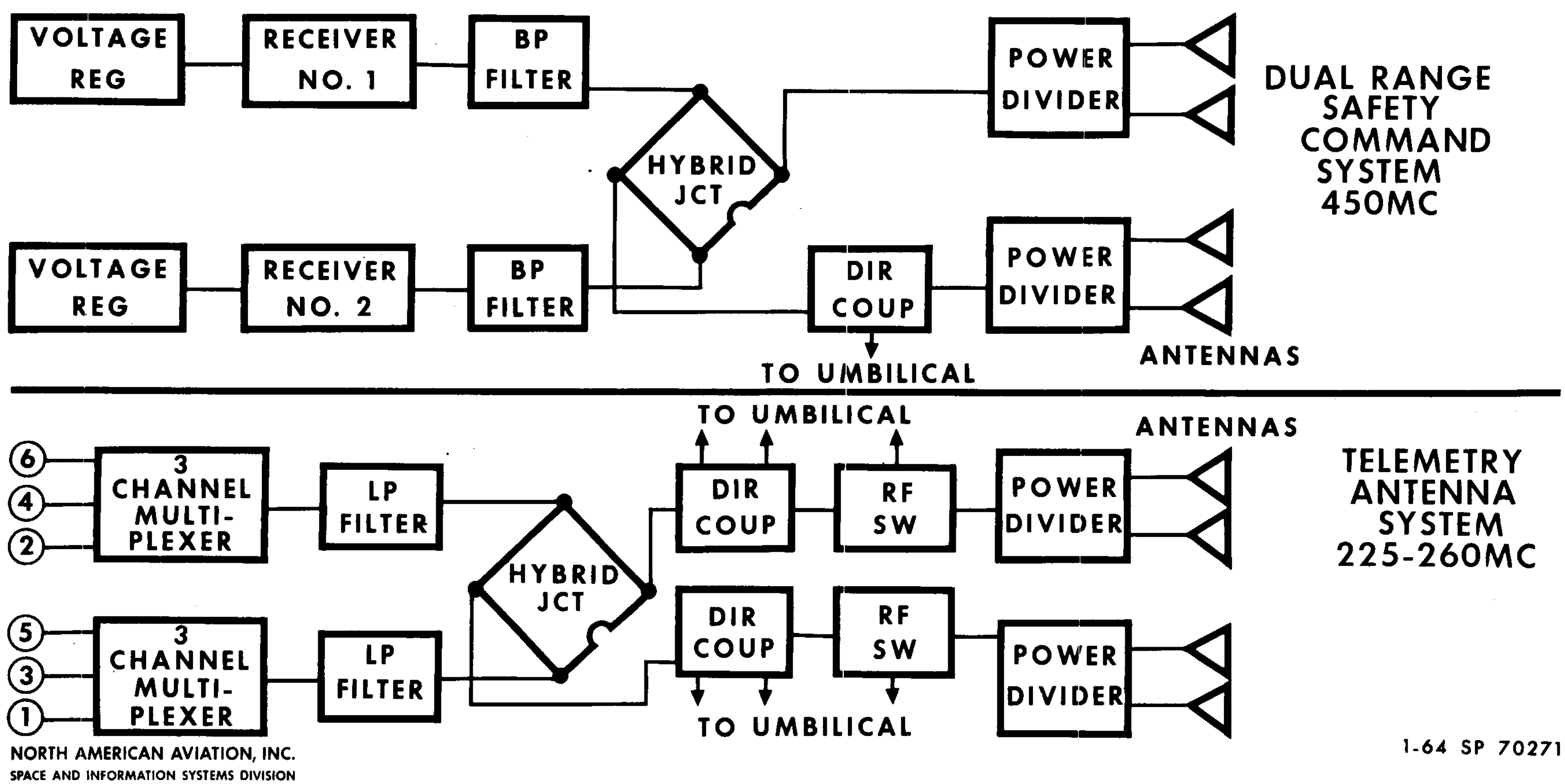

FIGURE 22 - RF SYSTEMS BLOCK DIAGRAM

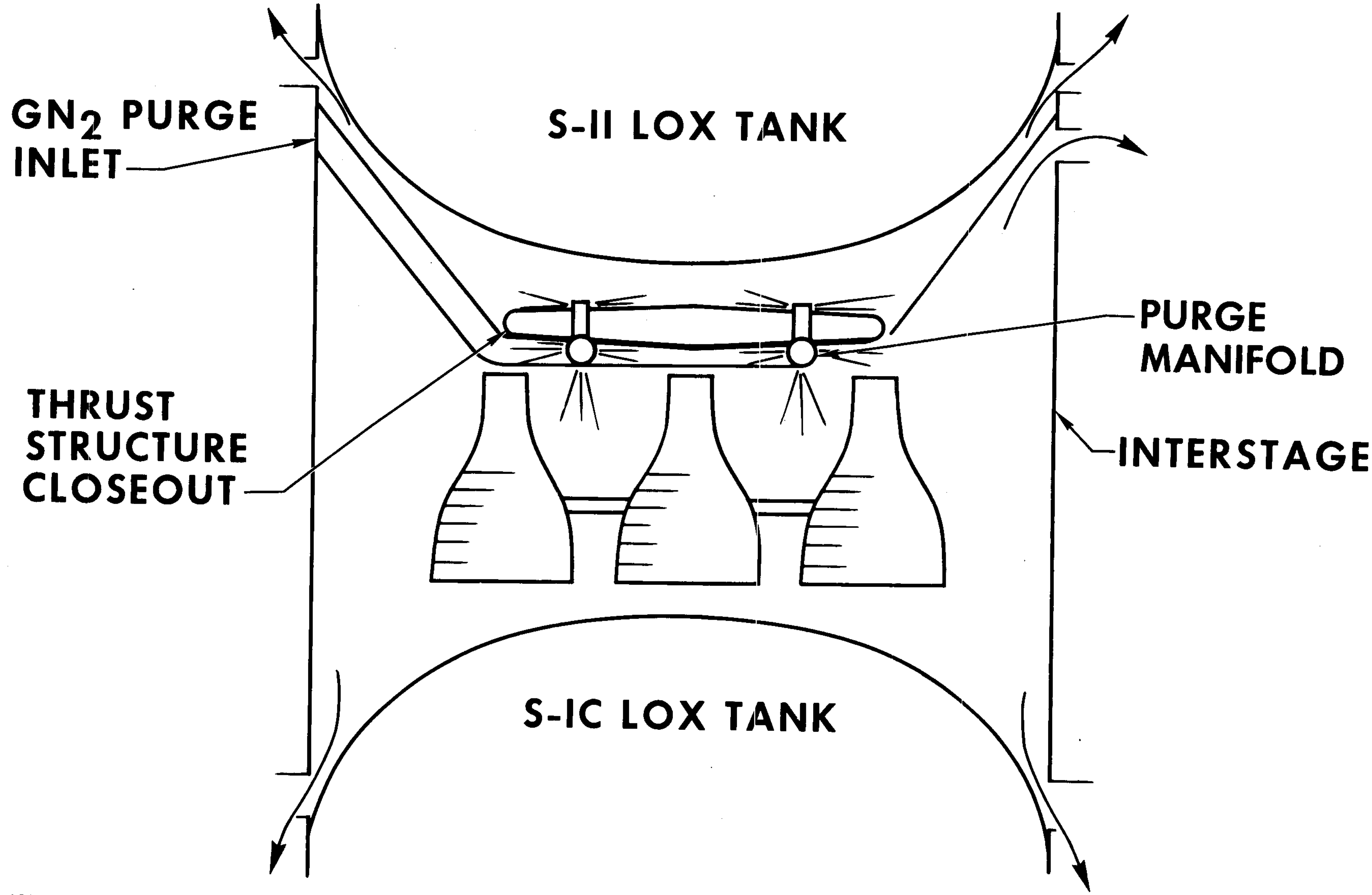

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FIGURE 23 - ENGINE COMPARTMENT CONDITIONING SYSTEM

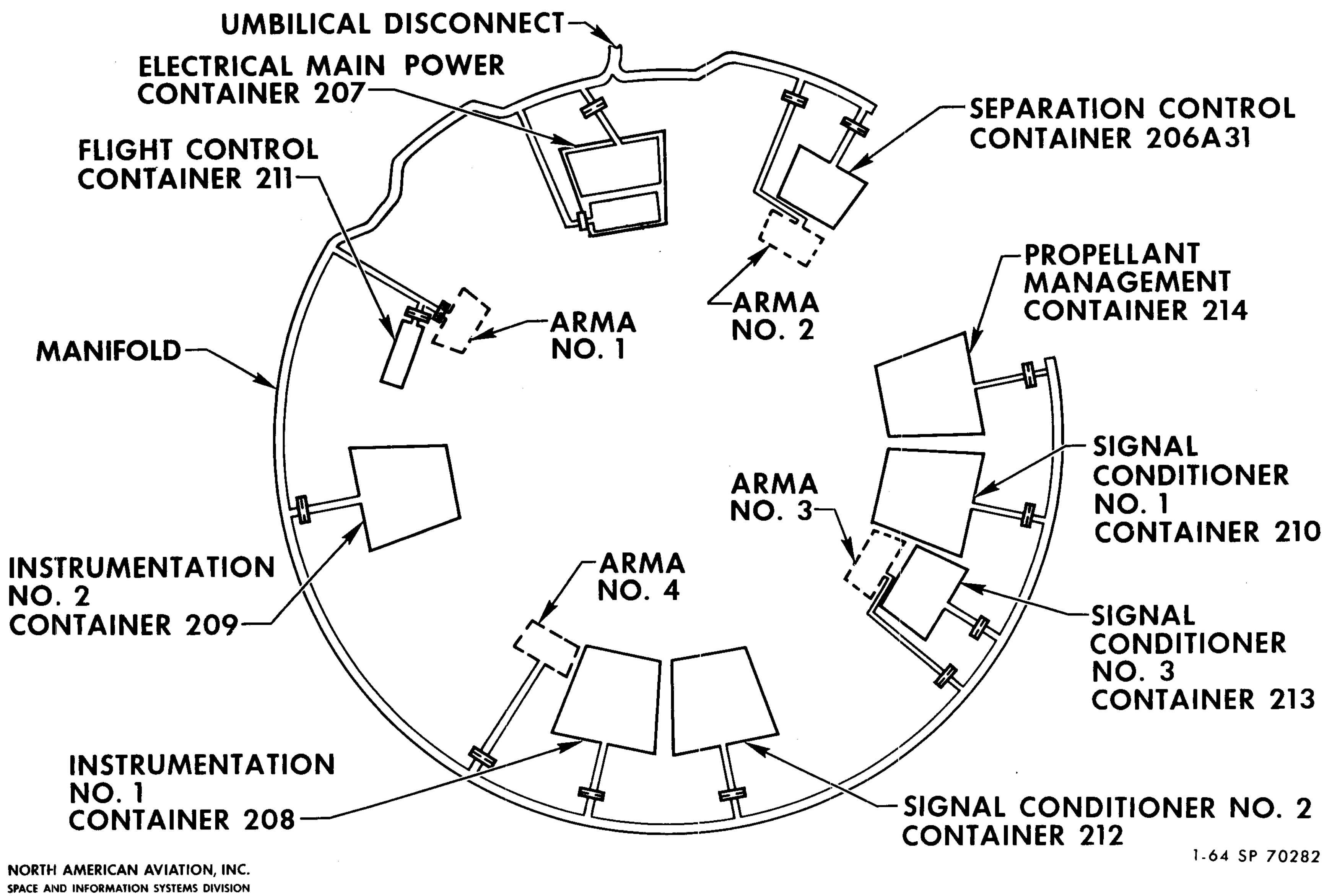

FIGURE 24 - THERMAL CONTROL SYSTEM FOR AFT EQUIPMENT CONTAINERS

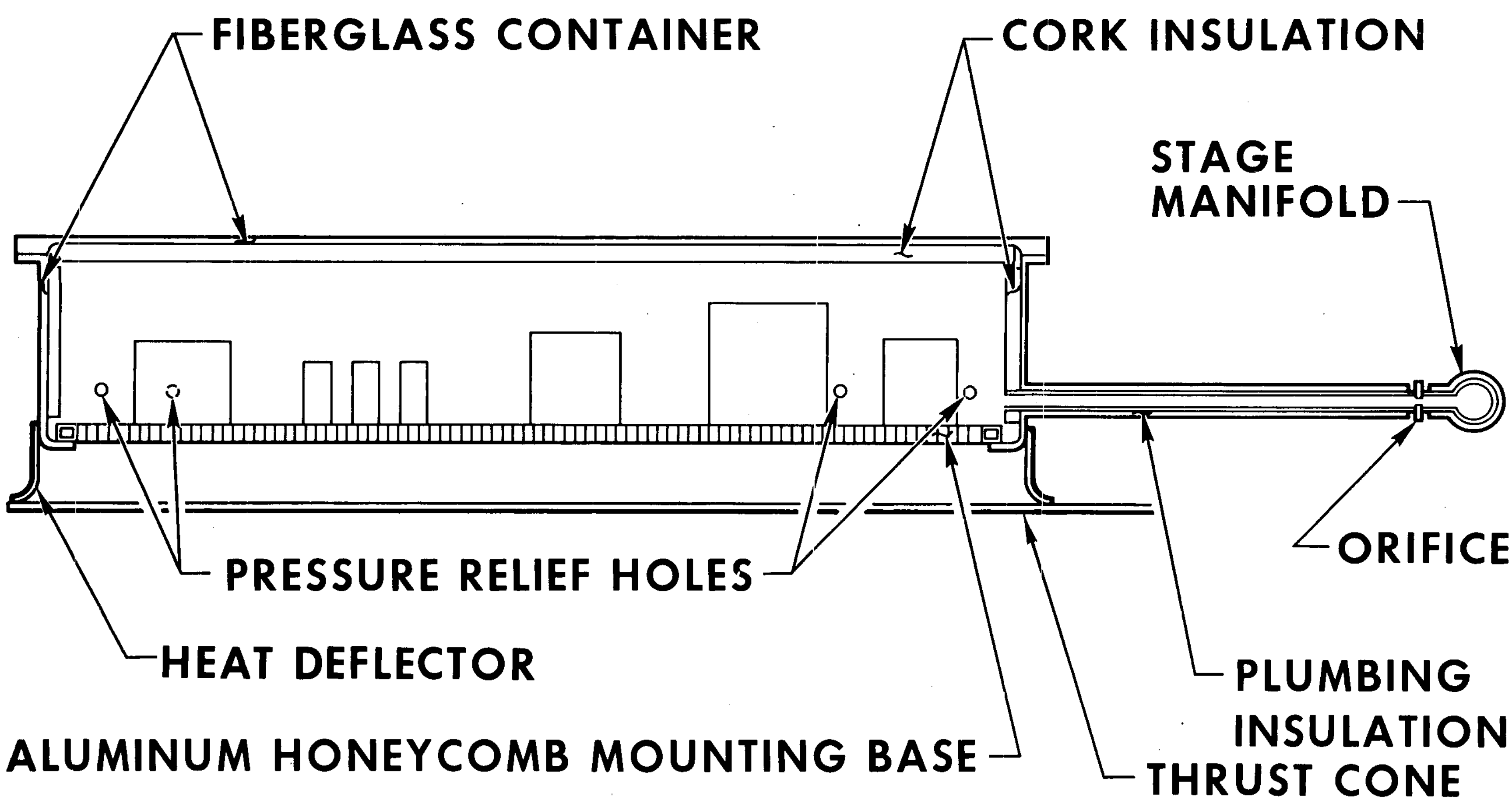

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FIGURE 25 - TYPICAL AFT EQUIPMENT CONTAINER

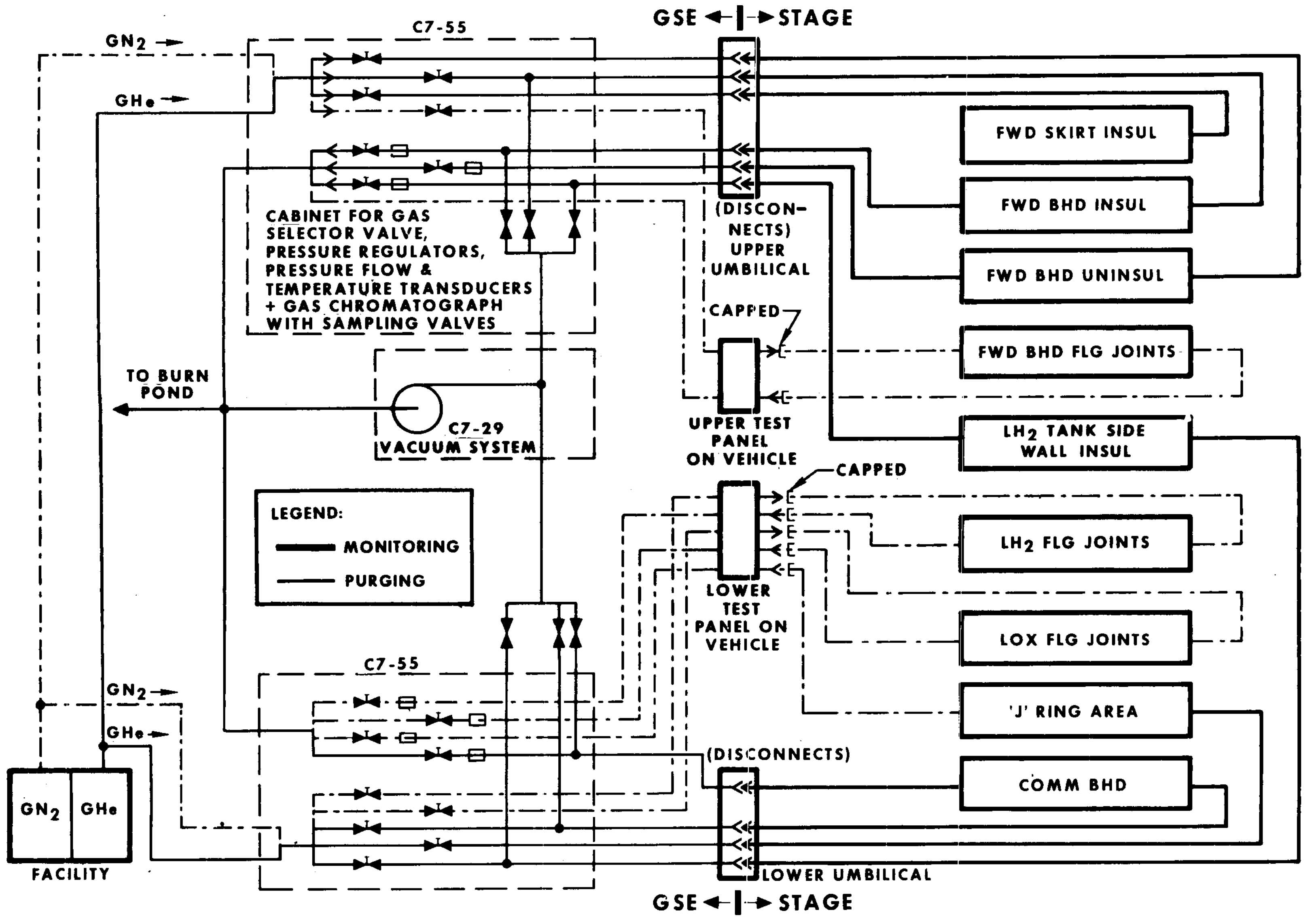

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FIGURE 26 - LEAK DETECTION & PURGE SYSTEM
MILA-LUT

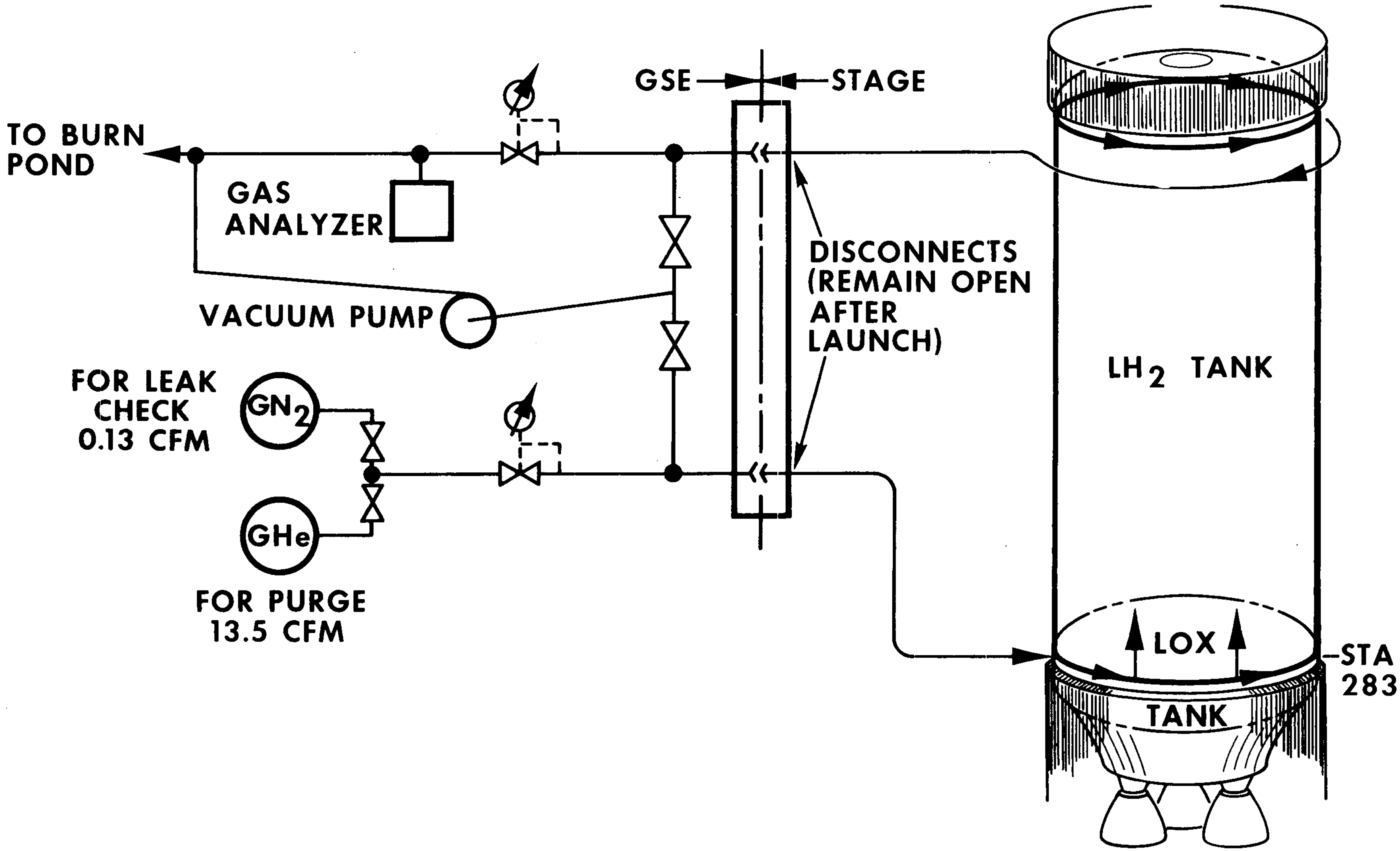

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FIGURE 27 - INSULATION LEAK DETECTION & PURGE SYSTEM
LH_2 TANK SIDEWALL

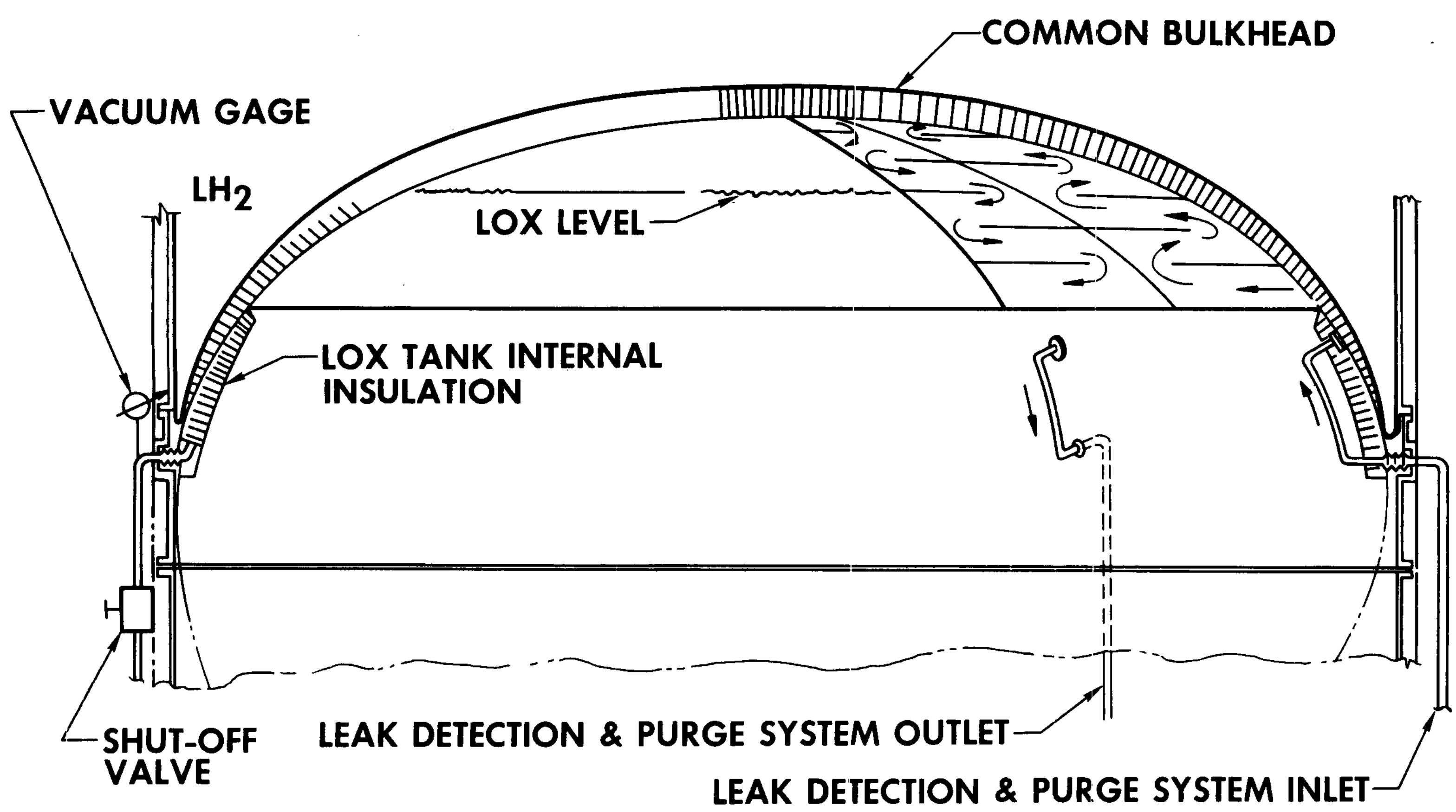

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FIGURE 28 - COMMON BULKHEAD LEAK DETECTION & PURGE SYSTEM

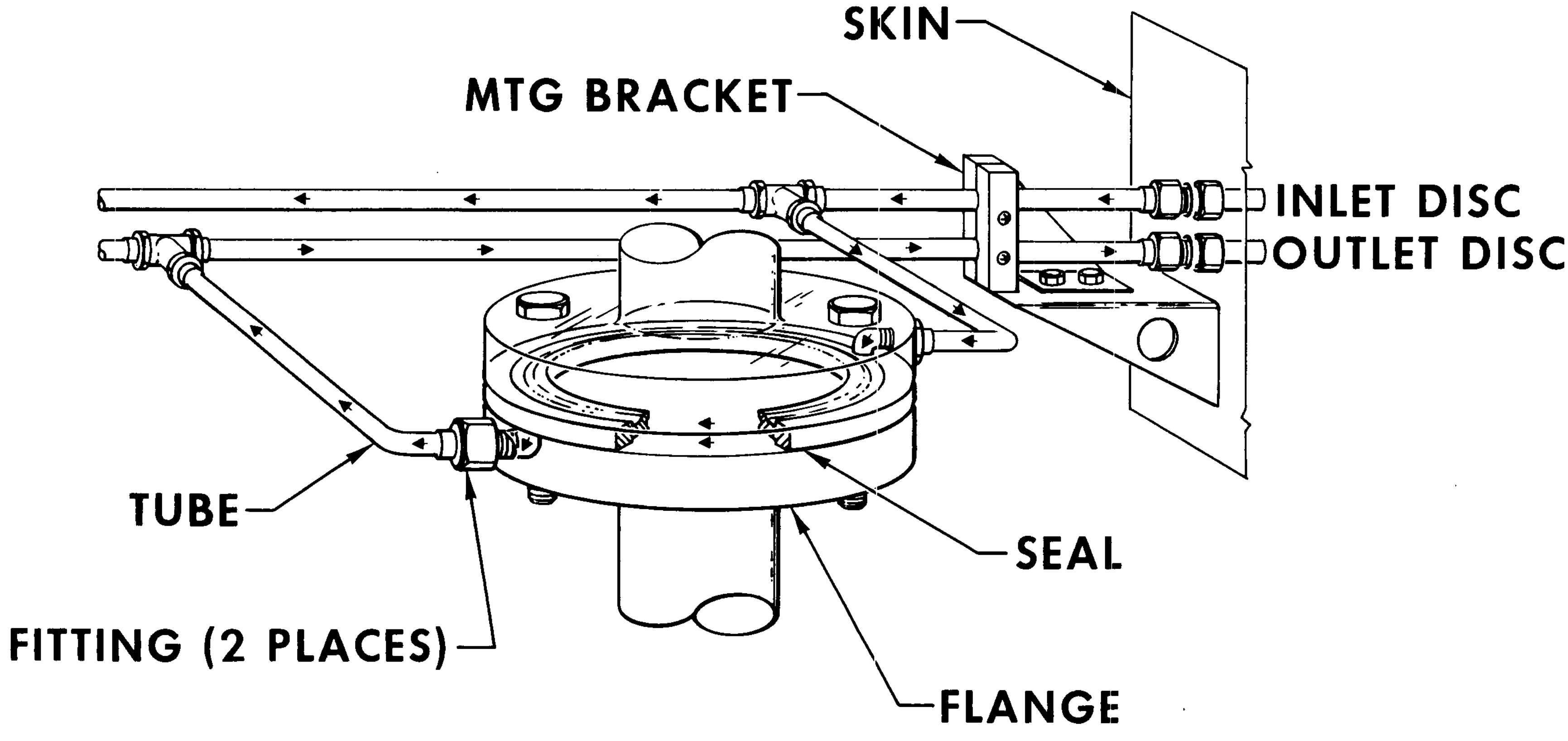

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FIGURE 29 - FLANGE LEAK DETECTION & PURGE SYSTEM
TYPICAL PROVISIONS